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JOURNAL OF THE AERONAUTICAL SCIENCES

Volume 3 AUGUST, 1936 Number 10

A Method of Air Flow Cinematography Capable of Quantitative Analysis

H. C. H. Townend, ***National Physical Laboratory, England***

(Received July 13, 1936)

THE question has often arisen why mankind acquired the ability to fly so late in life. The answer usually given is, for lack of adequate power, but this overlooks the fact—in recent years so amply demonstrated—that without any power even his own, it is possible to soar for many miles. The fact is all the stranger in view of the attention which soaring birds have attracted from time immemorial.

There is one aspect of motion through the air which distinguishes it from most of man's other activities—he cannot see what he is doing, i.e., doing *to the air*. Had he always been able to see just how the air behaved when struck by a stick or a bird's wing (and how great is the difference between the two) his efforts to imitate the birds of the air would have met with success much earlier.

Efforts to make air flow visible have received attention ever since the early days of aeronautics, and much help has been derived from visual methods of experiment. The method described below differs in one important respect from most others in that not only is the air made visible at a selected point in space, but its position in time is also under full control. This last feature enables quantitative results to be derived from the flow pictures, since velocities may be measured at any point and at any *time*.

Method of Making the Air Visible

The air is made visible at the desired position by warming it by some means. This changes the density slightly and therefore the refractive index relative to the surrounding air, and in consequence its presence can be revealed either by allowing it to cast a shadow on a screen which is illuminated by a point source of light, or by the Schlieren method as used in the knife edge test for optical systems. The latter is much to be preferred to the simple shadow method, and is especially suited for taking motion pictures.

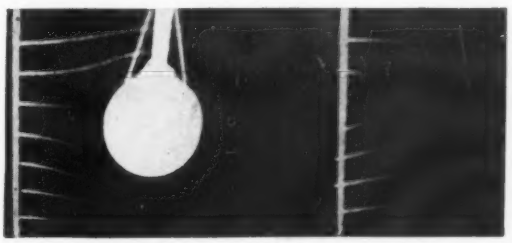

Fig. 1. Shadowgraph of flow past rotating cylinder.

Two types of heater may be used to provide the warm air: (1) a fine wire, heated electrically, which will produce a thin continuous band or "filament line"; (2) a small spark gap between fine platinum electrodes, across which a stream of sparks can be passed. The sparks heat up small masses of air, whose motions can be seen and measured, and in addition the tips of the electrodes themselves can be maintained at a high temperature so that they give rise to a filament line in the same way as a hot wire. For obtaining still pictures of steady motions a simple shadowgraph of a hot wire may suffice, but the spark method is necessary for quantitative work.

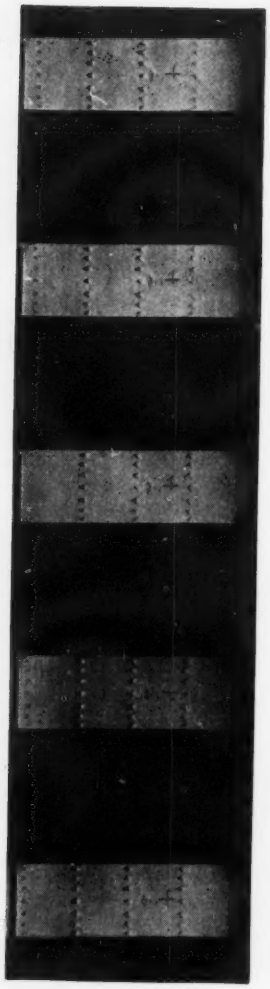

FIG. 2a. Streamline flow in pipe with smooth entry. Schlieren, edge vertical.

as it makes it possible to measure the displacements of the hot spots and deduce their velocities. It is then preferable to use the Schlieren method in conjunction with a cinema camera.

The shadow method has been described in references 1 and 2. An example of a shadowgraph is shown in Fig. 1; no camera is required for obtaining such pictures.

THE SPARK OR "HOT SPOT" METHOD

The hot spot method has been described in references 3 and 4. An excellent account of the Schlieren method itself will be found in reference 5.

The Schlieren method lends itself very well to the use of spark illumination, and will be described below in this form. For airflow photography this has the added advantage of extreme brevity of exposure which enables clear pictures to be obtained at high air speeds.

Owing to the great optical sensitivity of the Schlieren method, windows in the path of the light should be avoided. If they must be used they should be of high optical quality. An open jet wind tunnel is the most suitable means of providing the airstream as this allows the light to pass across the stream without interference.

If slow motion pictures of fleeting phenomena are required, a high speed camera is necessary, but for the majority of purposes similar effects may be produced stroboscopically.

The scheme normally used is as follows. Two contact breakers are driven synchronously by an electric motor, which may be coupled by some form of clutch to the cinema camera. One contact breaker interrupts the primary circuit of a spark coil which delivers the illuminating sparks. The spark gap is situated very near the centre of curvature of a concave mirror, and this mirror must be large enough to cover the whole field over which pictures are required. After reflection the light converges again to give an image of the spark at a point very close to the spark itself. Here the light is intercepted by the Schlieren diaphragm (knife edge); this cuts off all but a small amount of light, which is allowed to pass into the camera.

The second contact breaker causes a second spark coil to discharge across a group of spark gaps in series at selected points in the airstream which instantly heat up the air in the gaps. The resulting "hot spots" then traverse the optical beam during their passage round the model, and if the light spark occurs while they are in the field of the mirror their instantaneous positions will be recorded on the film. If for every revolution of the camera shutter one hot spark and one light spark occur then on projecting the film the airflow, if a steady motion, will appear at rest, on the principle of the stroboscope. By adjusting the relative phase of the contact breakers, the position of the row of spots relative to the electrodes may be adjusted, and if a slow continuous change in the phase is maintained a slow motion effect may be simulated.

It should be remembered that the models shown in the pictures were all without taper along their span, whilst the optical beam was conical, hence the models themselves are somewhat foreshortened. The flow lines are situated at mid-span, and it follows therefore that the section along which the flow is made visible lies inside the profile shown in the pictures which is a photograph of the end nearest the camera.

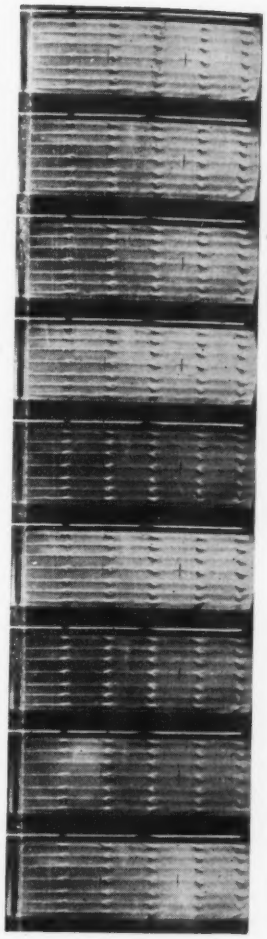

FIG. 2b. Streamline flow in pipe with smooth entry. Schlieren, edge horizontal.

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[1] *On rendering air flow visible by means of hot wires*, R. & M. 1349, British Aeronautical Research Committee.

[2] *Hot wire or spark shadowgraphs of the airflow through an airscrew*, Phil. Mag. XIV., p. 700 Oct., 1932.

[3] Annual Report of National Physical Laboratory for 1932.

[4] *Statistical Measurements of Turbulence in the flow of air through a pipe*, Proc. Roy. Soc. A. Vol. 145, 1934.

[5] ***Das Toeplersche Schlierenverfahren***, Forschungsheft 367. July/August, 1934, H. Scharum.

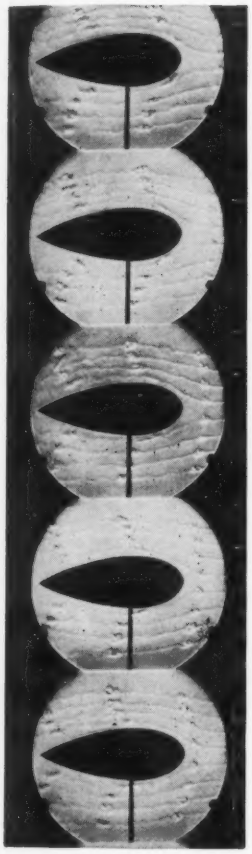

FIG. 3. Flow past streamline body.

FIG. 4. Two-bladed airscrew working at high thrust.

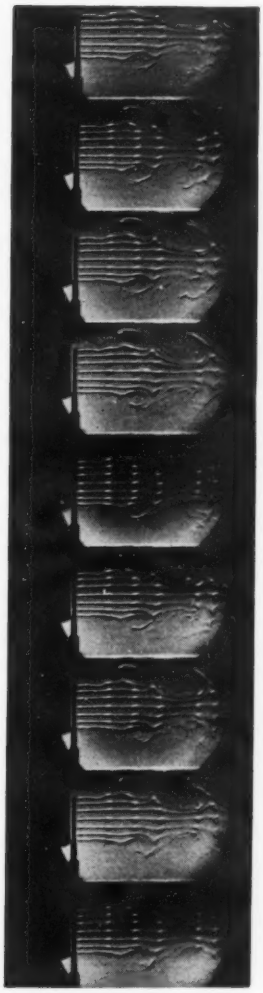

FIG. 5. Air jet discharging into atmosphere.

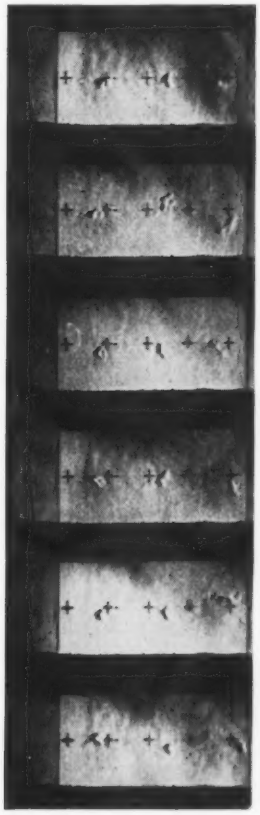

FIG. 6. Turbulent flow on axis of pipe.

TYPES OF FLOW PICTURES

The different types of flow pictures fall into two main classes according to whether a normal speed or a high speed camera is necessary.

NORMAL SPEED CAMERA

(a) *Steady Motions:* A film of a steady motion, such as the potential flow round a streamline body, taken with a fixed phase relation between the hot and the light sparks, yields what is virtually a still picture. This assumes that the flow is non-turbulent; if turbulence is present successive pictures will fluctuate slightly about the "mean" picture, producing a shimmering effect when the flow is observed visually or when the film is projected. As practically all air streams are slightly turbulent this provides a means of obtaining an accurate mean picture; all that is necessary is to allow a number of exposures to fall on a single frame of the film. Pictures of this kind however are best made with a still camera.

Fig. 2 shows the simplest case of steady motion, the almost non-turbulent flow near the entrance of a 3″ pipe with converging bell mouth. In making Fig. 2a the edge of the Schlieren diaphragm was perpendicular to the direction of the airstream while in making Fig. 2b it was parallel to it. In the latter case the Schlieren effect is due to vertical deviation of the light rays and hence

reveals the horizontal filament lines due to the hot electrodes themselves. Since the filament lines produce no deviations parallel to themselves there will be no Schlieren effect when a vertical knife edge is used and hence they remain invisible in Fig. 2a although they are still there. The hot spots however show up, but their appearance is slightly different. In Fig. 2 the two sets of sparks are synchronous (fixed phase), and hence on projection produce a stationary picture.

In Fig. 3 a slow phase change exists and on projection a slow motion effect is observed. The irregularities are due to tunnel turbulence; the shimmering effect they produce would not occur if a true slow motion camera had been used (see later).

(b) *Periodic Motions:* Fig. 4 is an example of a periodic motion. It shows the flow past an airscrew blade working at a high thrust coefficient. In this case there is a third frequency, namely, that of the blades. The phase relations were arranged so as to give, stroboscopically, a slow motion effect. The hot spots were produced synchronously with the blade frequency, while the light sparks were given a slow lag, so that each picture shows the condition of affairs at a point slightly later in the cycle than the previous one. On projection therefore the flow appears to move slowly downstream whilst the blade appears to rotate slowly at the corresponding speed. The vortices springing from the tips of the blade can be clearly seen, while a further feature of interest is the vortex sheet springing from the trailing edge of the blade. This sheet is represented by the series of breaks in the filament lines where they are cut by the sheet. (see reference 2).

This type of picture will be discussed further in *"The Flow Past Aerofoils."*

Fig. 5 shows a jet of air discharging into a still atmosphere. The flow in this case has a natural periodicity due to the shedding of vortex rings at the jet boundary. The speed of the camera was adjusted to be equal to that of the natural frequency of the jet pulsations, and on projection the flow pattern appears stationary. (Reference 7). At a slightly slower filming speed an axial pumping action would be observed.

(c) *Turbulent Motions:* Although the frequencies involved in turbulent motion are high, and require a high speed camera to record them fully, it is quite possible to make statistical measurements of the turbulent velocities with a normal speed camera. Fig. 6 shows the flow at the centre of a 3″ square pipe far from the entrance at a Reynolds number well above the critical value. A hot spot is made in the airstream and its photograph taken at a known interval of time later. Measurements of its position relative to a mark (+) on the glass window enable its component velocities to be determined. The pictures are quite independent of one another; the observations from all the pictures are analysed statistically to give the mean speed and the turbulent components about the mean. Measurements of the distribution of turbulence across a pipe have been made by this method and are described in reference 8.

It is of course necessary in such measurements to be sure that the hot spot has moved along a straight or sensibly straight path during its passage from the electrodes to the point at which it is photographed, as otherwise its displacement relative to its mean position is not a measure of its turbulent velocity component. In the case of the pipe experiments just referred to this was done by making separate tests in which the illuminating spark was replaced by an arc lamp focussed on a sharp edge (Schlieren edge) and a rotating shutter was moved across the beam of light in a plane near the pipe window. The disc had a moderately wide slit in it, and its speed and the phase of the slit were so adjusted that the slit moved along the air stream at the same speed as the hot spot. The actual path traced out by the spot was thereby recorded as a line on the film, and in only a small number of pictures were the paths even slightly curved over the distance measured. (See *"Dark Ground Illumination."*)

Recently, the accuracy of the method has been improved by certain modifications. Firstly, a multiple discharge is used in the illuminating spark-gap by merely increasing the primary current. This produces a group of 4 or 5 sparks every time the primary current is interrupted. The time intervals between the constituent sparks in the group are arranged to be of the order of 0.001 second or less by using a suitable condenser across the gap. Secondly, a motor carrying a spider with several radial arms, is placed at a convenient position in the field of view where it will be photographed by each spark in the group. Its angular displacement gives a time scale. At another convenient position two gauge points are placed whose distance apart serves as a standard of length. Both spider and gauge points are photographed on the film. To avoid fogging due to the multiple exposures given to each picture, the Schlieren diaphragm is adjusted to intercept the image of the illuminating spark completely so as to give a dark background, on which the several images of one spot appear as bright marks. Finally, since this adjustment means that in practice the gauge points and spider arms will be almost invisible in the picture, the Schlieren effect in those parts of the field is neutralized locally by placing pieces of plate glass in the path of the light, and inclining them at a suitable angle. This allows full illumination of gauge points and spider arms, which can be adjusted independently of the Schlieren adjustment.

[6] *Improvements in the Schlieren method of photography.* Journal of Scientific Instruments, Vol. XI., No. 6, June, 1934.

[7] *Flow induced by a jet of air.* R. & M. 1634, British Aeronautical Research Committee.

[8] *Statistical measurements of turbulence in the flow of air through a pipe,* Proc. Roy. Soc. A. 145, 1934.

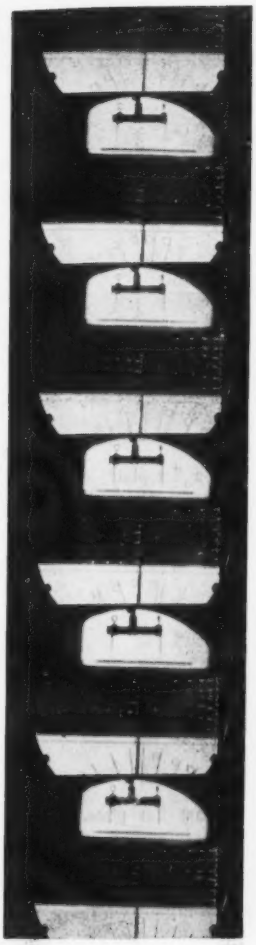

FIG. 7. Turbulence behind a cylinder.

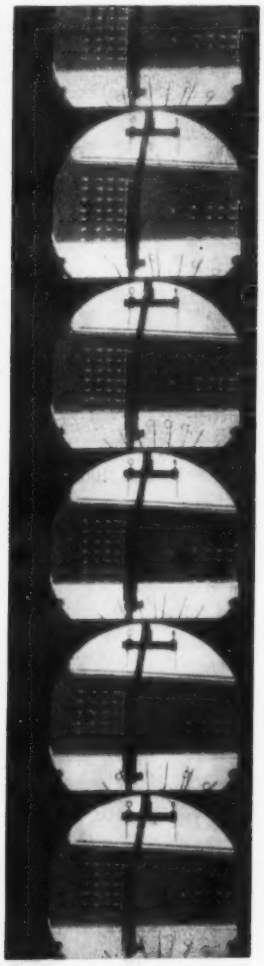

FIG. 8. Flow with cylinder removed.

These modifications have the following advantages:

(1). Each hot spot is photographed at least twice so that if the spot as a whole is distorted by the turbulence, which is often the case, it usually remains possible to identify some point in the spot, whose motion can be observed. This considerably reduces the *effective* size of the air mass observed, and increases the accuracy.

(2). By using three or more sparks in the group the path of the spot can be traced, and any curvature therein detected.

(3). The time intervals are recorded on the film itself, as angles turned through by the arms of the spider. Thus the irregularities which generally occur in the timing of the sparks are automatically eliminated since for each position of a hot spot there corresponds an image of a spider arm, which affords an accurate time scale. In taking a film therefore it is only necessary to control the spider speed accurately, the camera and light spark being driven together at a speed whose value is immaterial to the measurements.

Fig. 7 shows the field of flow in the wake of a cylinder taken by the above method. The cylinder itself does not appear in the picture. This film has been analysed to determine the turbulence in the wake (reference 9). At the top of each picture are the gauge points ($2\frac{1}{2}$″ apart). At the bottom are the several images of the spider arms. There are 8 arms on the spider, each alternate arm carrying a small hollow disc to enable it to be distinguished from its neighbor. In both cases the dark background has been neutralized locally by the interposition of tilted glass plates. In the centre the field is dark. On the right are six spark gaps giving sparks 0.02″ in length, spaced $\frac{1}{2}$-inch apart. They are situated in a plane 15 diameters behind the cylinder ($\frac{3}{8}$″ diameter); in the centre are 4 gaps 25 diameters behind, in a slightly different lateral plane. The outer spark gaps are practically outside the wake. The filming speed was 14 pictures per second.

Fig. 8 is a similar picture taken with the cylinder removed to show the flow in the empty tunnel.

The case of turbulence behind a cylinder is a rather severe test of the method. In this case, as in others, good agreement has been obtained with the results measured by other methods, e.g. the ultramicroscope. (reference 10). For more normal motions velocity measurements are comparatively simple since little distortion of the spots occurs and their motion can be followed further downstream.

High Speed Camera

(a) *Turbulent Motion (continued):* Whilst the method just described is convenient for measuring turbulent velocities such as those in a pipe, it gives essentially only a series of disconnected snapshots. A closer examination of the structure of turbulence, e.g. that which exists on the upper surface of a stalled aerofoil demands the use of a high speed camera, which allows the evolutions of air masses to be watched as the motion proceeds. To render visible such regions of turbulence it is convenient to place a fine wire heated electrically somewhere in the region. In appearance pictures taken in this way are very similar to those taken with smoke, but have the advantage of being visible at any air speed.

(b) An important class of motions for which a high speed camera is necessary includes transient motions such as occur when an aerofoil suddenly changes its incidence, or when a body starts from rest. In such cases the time lag which exists between the change in the motion of the body and the resulting change in the air flow pattern can be measured.

In taking a high speed picture, the whole shot may only take one second or so, and hence it is essential

[9] National Physical Laboratory Annual Report, 1935.

[10] *On the static pressure in fully-developed turbulent flow,* A. Fage. Proc. Roy. Soc., 1936.

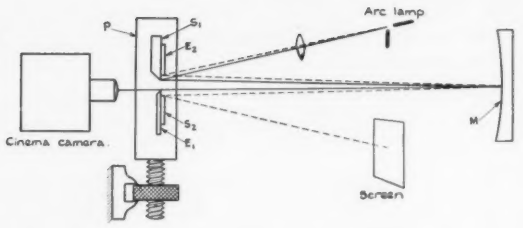

FIG. 9. Diagram of Schlieren edges arranged to give duplicate image for visual observation.

that the flow being photographed should be observable on a screen during filming so that the shot may be properly timed. This may be done by arranging matters as shown in Fig. 9. An arc lamp is focussed on the edge of a stainless steel mirror. S_1, and an image of this edge is formed near the Schlieren edge E_1. Only axial rays are shown in the diagram, and to avoid confusion the initial and final rays are shown displaced outwards instead of lying along the main optical axis. An opaque shield, E_2, is placed with its straight edge close to that of S_1, and an image of the edge is formed near S_2 which is a concave galvanometer mirror having a straight edge ground on it. The edges of E_2 and S_2 constitute a second Schlieren system independent of S_1 and E_1, and the image due to them is reflected and focussed by the mirror S_2 on to a screen which may be observed while filming.

FILMS ILLUSTRATING AIR FLOW

The methods which have been described will be illustrated by examples many of which are taken from a film that has recently been made at the National Physical Laboratory. This shows various flow phenomena, and is part of an educational film on the Theory of Flight made for the Air Ministry with whose permission these pictures are reproduced.

It should be remarked that for analytical work involving the measurement of the displacements of hot spots, it is desirable that the sparks should be as small and as weak as possible, consistent with adequate visibility. This usually means that the electrodes are not warm enough to produce visible filament lines. When flow pictures are required for pictorial purposes as in an educational film much hotter sparks are preferable in order that both hot spots and filament lines may be clear, and extend well downstream.

Many of the pictures shown were taken with a normal speed camera, using the phase-changing mechanism already described to slow the motion down somewhat. The other pictures were taken with the Western Electric Company's high speed camera at speeds varying from 500 to 2300 pictures per second. This camera contains an arrangement by which a time scale reading to 1/1000th second is recorded on the

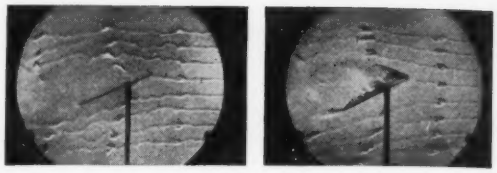

FIG. 10a. The flow past a flat plate.

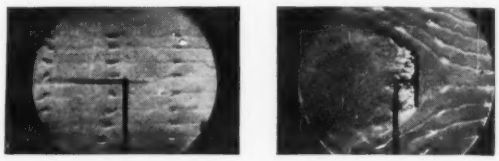

FIG. 10b. The flow past a flat plate.

FIG. 10c. Initial motion past flat plate.

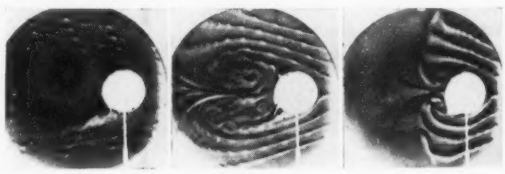

FIG. 10d. Stages in the initial motion past a circular cylinder.

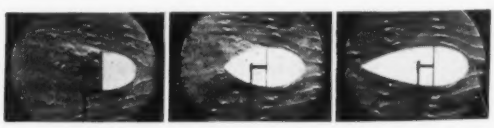

FIG. 11. Stages in the streamlining of a bluff body.

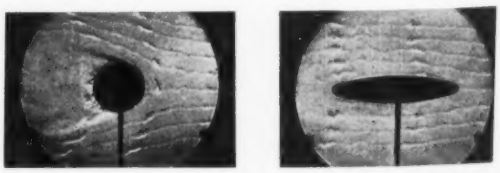

FIG. 12. The flow past circular and elliptical wires.

FIG. 13. Effect of a Townend Ring on the flow past an engine nacelle.

FIG. 14a. Slotted aerofoil, unstalling.

film so that accurate measurements of the speed of any event may be made.

Where dead air regions occur, they have been rendered visible by placing heated wires within them, usually lying along the wind direction in contact with the surface of the body at mid span. An example of this is given in Fig. 10-a where the flow past a Flat Plate is shown with and without a hot wire in the wake.

Fig. 10-b shows the plate at angles of attack of 0° and 90°. Fig. 10-c shows one stage in the initial motion past the plate at 90°, obtained with the high speed camera, and Fig. 10-d shows three stages in the initial motion past a cylinder. The two initial vortices can be seen rolling up, followed by a series of smaller vortices from which ultimately the surface of discontinuity develops. The air speed is so low in the early stages that individual hot spots are barely separated.

Steps in the streamlining of a bluff body (flat plate) are shown in Fig. 11. Starting with the flow past a flat plate at 90°, as shown in Fig. 10-b, the addition of a round nose makes a large reduction in the size of the wake, but it is not till an adequately tapered tail is added that the wakes become small. Actually the short-tailed model in Fig. 11 gave a very much smaller wake than is there shown when the wind speed was raised, illustrating scale effect on drag.

The superiority of a bracing wire of elliptical section over one having a circular section in indicated in Fig. 12.

The influence of a Townend Ring on the turbulence behind a radial engine is illustrated in Fig. 13. The "nacelle" was represented by a short length of thick strut section, and the engine was represented by a row of 4 cylinders on top and 4 below, the cylinders being separated from each other by about one cylinder diameter. The size of the wake seen behind the cylinders is probably greater than would occur with a body of revolution, but serves to illustrate the effect of the ring. The ring was represented by two small aerofoils. There is a marked reduction in the turbulence when the ring is placed over the engine cylinders; this becomes noticeable while the ring is still well upstream.

THE FLOW PAST AEROFOILS

Fig. 14-a shows the effect on a stalled aerofoil of bringing up to the leading edge an auxiliary aerofoil to form a slot of the Handley Page type. The picture shows the slat just after it has reached its position. There is a time lag in the change over to the unstalled condition of flow, which however takes place very suddenly once it begins. Thus it is practically complete between two pictures (Nos. 3 and 4), i.e. in 1/20th second.

We may here notice one way in which the stroboscopic method of obtaining these pictures fails to depict the flow accurately. In one picture interval (i.e. 1/20th

FIG. 14b. Change in circulation due to unstalling.

second) the air moves a distance equal to 4 hot spot intervals, as there are 4 discharges to each light spark discharge. This corresponds to the full width of the field of view. The hot spots *appear,* however, to have moved only about 1/12th chord in that time, giving the impression that the faster air has blown away the dead air before it has reached it. The same criticism however does not apply to the filament lines, and in practice it takes a very vigilant eye to detect the inconsistency, when the film is projected. Caution must however be exercised when seeking to interpret such films picture by picture.

Fig. 14-b shows the same aerofoil with and without the slat taken under different conditions from those of the previous figure. In the first place the light spark was "double", the two flashes being roughly 1/1000th second apart. The hot spots have therefore been photographed twice, so that each double image represents the ends of a velocity vector, the whole field being thus mapped at each picture. In the second place there was no phase change between the pictures (giving a "stationary" picture on projection) and consequently the picture with the slat may be superposed on that without it to ascertain the velocity changes due to the slat. A noticeable feature in such a comparison is the increase in the circulation with the slat present. When such a picture is projected, the apparent airstream velocity is reduced to zero, while the change in circulation remains so that the whole flow pattern near the aerofoil appears to rotate slightly in an anti-clockwise sense at the moment when unstalling occurs.

In connection with this type of picture it is of interest to notice that by its means "paths of particles" and "filament lines", which differ in the case of non-stationary flow patterns,* although they are deducible from one another, may be photographed simultaneously. If, for example, the flow through an airscrew, (see Fig. 4) were photographed with double illuminating sparks, the result would be similar to but much more accurate than that obtained by superposing two neighbouring pictures of Fig. 4. The paths of the particles would then be shown intersecting the filament lines. In such a picture the streamlines could be sketched in by drawing lines whose direction is at every point that of the particle path at that point. Filament lines, though they are the most readily obtained are the least easy to interpret in a still picture, since the inspection of one picture alone tends to mislead by suggesting that the air actually moves along such lines. When, however, such a picture as that of Fig. 4 is projected, no confusion arises.

SCALE EFFECT

The influence of Reynolds Number on the flow past an aerofoil is shown in Fig. 15. In picture No. 1 (bottom left hand corner) the angle of attack and the wind speed are both low, and the flow is unstalled.

* See Bairstow's *"Applied Aerodynamics"*.

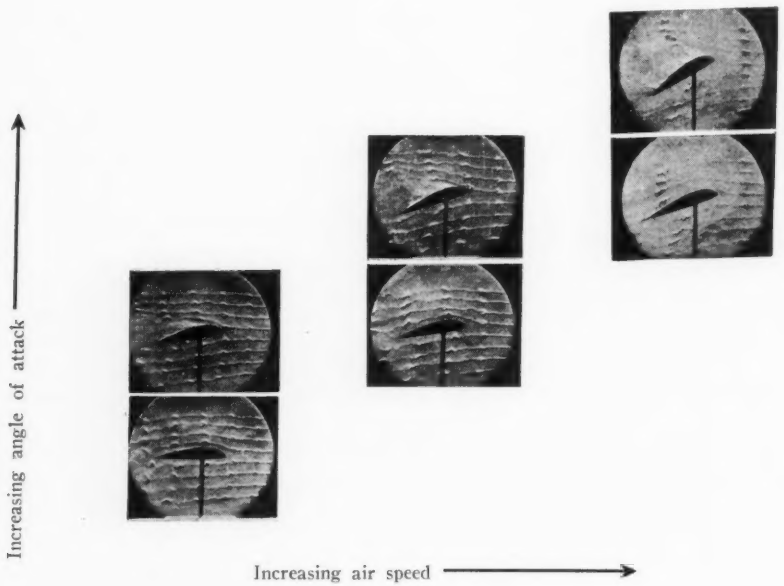

FIG. 15. Scale effect on an aerofoil.

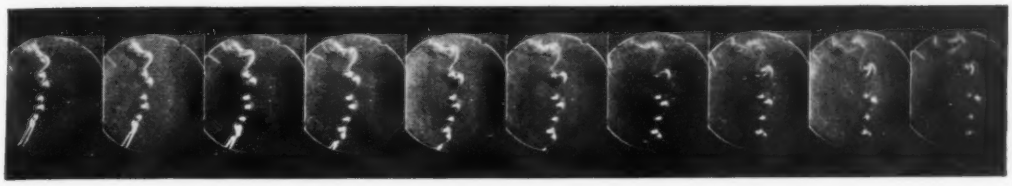

FIG. 16. Aerofoil starting from rest. Note vortices "rolling up."

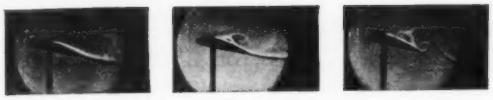

FIG. 17. Starting from rest in wind tunnel; low acceleration.

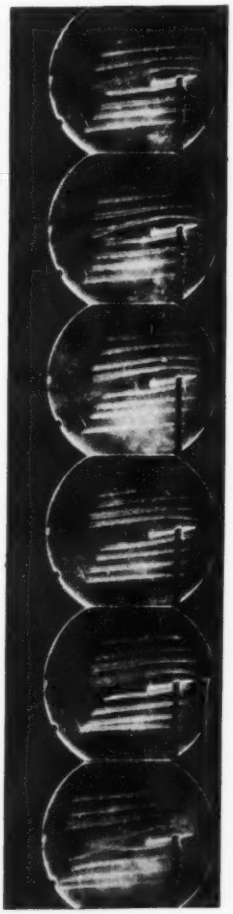

FIG. 18. Paths of particles.

In picture No. 2 the angle has been increased causing the aerofoil to stall. In picture No. 3 the air speed has been increased, by an amount proportional to the increase in spacing of the hot spots. This has caused the flow to unstall. After a further increase in angle (picture No. 4) the flow again stalls and is once more unstalled by an increase in the speed (of about 100%, picture No. 5). Finally in picture No. 6, the angle is increased to an extent which permanently stalls the flow.

AEROFOIL STARTED FROM REST

In certain cases the slight convection due to the buoyancy of the heated air may be serious, though usually it is not so above air speeds of 2 or 3 feet per second. For accurate work at low speeds the effects of convection can generally be circumvented by arranging the apparatus with the optical axis vertical, so that convection does not give the hot spots any velocity across the field of view. As an illustration of this Fig. 16 shows an aerofoil starting from rest in still air. A wire lying along the upper and lower surfaces is heated electrically, the current being turned on just before the motion commences. The acceleration is such that the circulation develops as a series of discrete vortices. This may be compared with the much slower acceleration obtained in a wind tunnel by just turning on the wind—Fig. 17—in which the initial vorticity comes off as a smooth sheet. In the first picture the flow has moved about 1 chord from the start. The next two pictures show the second and third vortices.

Reverting to Fig. 16 it is seen that, after the aerofoil has passed, the vortices, being unstable, tend to group themselves and roll up into larger vortices, a process which can be quite clearly observed in the figure.

DARK GROUND ILLUMINATION

For some purposes it is useful to use a dark background against which the hot spots appear as bright dots. One method of doing this, already referred to *(Normal Speed Camera)* is to adjust the Schlieren edge to intercept the image of the illuminating spark completely but this causes one side of the hot spots to disappear, which is sometimes undesirable. An alternative method (reference 6) which gives a symmetrical

image of the hot spots is to focus an arc lamp on to a narrow silvered strip with parallel edges situated at the centre of curvature of the mirror. In the critical adjustment, the image (inverted) of the strip is thrown back on to the strip itself and intercepted by it, so that the field appears dark in the camera. Instead of the hot spot appearing as a dot with one side bright and the other dark against a grey ground, both sides appear bright with a fine dark line between them, against a dark ground. Fig. 16 was taken in this way.

Spark illumination may be used with this arrangement if an image of the spark is focussed on the silver strip. With an arc lamp it is necessary to use a stroboscope disc with narrow slits.

Particle Paths

If the above arrangement, with arc illumination, is used in conjunction with the ordinary cinema camera, the hot spot will trace out its actual path, provided the heating spark is phased correctly relative to the camera shutter. An example of this is shown in Fig. 18, which shows particle paths round a flat plate.

The length of the path of a spot is a measure of its average velocity.

In the last picture of Fig. 18 two paths will be seen to have crossed each other. The spot which passed over the plate had a higher velocity than that which passed under it, as is shown by the greater length of its path. The way in which the spots moving close to the plate traverse the wake, often without losing their identity, can be clearly seen in the slow motion film which was taken of the same model. This must be because the spot forms part of a large eddy which maintains its structure intact for some distance aft of the plate. When the spot is on the edge of the eddy it becomes involved in the neighboring eddy, and is diffused into the wake immediately.

Equipment for Laboratory Instruction in Aerodynamics

KENNETH G. MERRIAM, *Worcester Polytechnic Institute*

(Received July 13, 1936)

IN developing aerodynamic test equipment for the use of undergraduate technical students, it is well to observe two general guiding principles. First, the primary equipment should be small-scale, so that the requirements of first cost, housing space and operating power will be modest. Second, the auxiliary equipment, for making measurements, should be rugged, inexpensive, simple, sensitive and accurate.

The heart of the aerodynamic laboratory is the wind tunnel. On page 56 of the November 1935 issue of this JOURNAL is shown a wind tunnel which was designed to satisfy the above first guiding principle. The air is circulated by a 5 hp. motor; the normal maximum operating air speed, with normal model obstruction, is about 78 m.p.h., (115 ft. per sec., corresponding to a velocity head of 3 inches of water), but there is some reserve capacity beyond the limit of the 3-inch inclined manometers used. The cross-sectional area of the working region, which can be either "open" or "closed," as desired, is a little more than two square feet. Radial traverses anywhere in the working region indicate an air velocity variation from mean of about one per cent. The velocity can be controlled at any value from zero to the maximum mentioned. Experience with this machine over a seven year period has proved that it more than fills requirements for instruction purposes.

The main purpose of this paper is to submit two illustrations to indicate that it need not be difficult to meet the demands of the second guiding principle, mentioned in the opening paragraph.

Consider first the problem of measuring aerodynamic forces. Although the laboratory has developed a six-element balance, about 98 per cent of the work in force measurements is actually done with the arrangement shown in Fig. 1.

The drag-measuring device is a permanently rigged affair, shown, in Fig. 1, by unbroken lines. Disregarding all broken lines in Fig. 1 for the moment, it will be noted that the scheme amounts to a conventional wire balance, to which is connected, at "A," a "drag frame" which, in turn, is suspended by long vertical wires. When a model is to be tested for drag, it is attached to the drag frame by suitable supports. The frame is permanently equipped with sliding crossbars, clamps and other aids, so that little time or effort is required to attach and align a model.

Wires shown as GH, G'H', AB, BC and BR are actually double wires in parallel planes, so that no wires

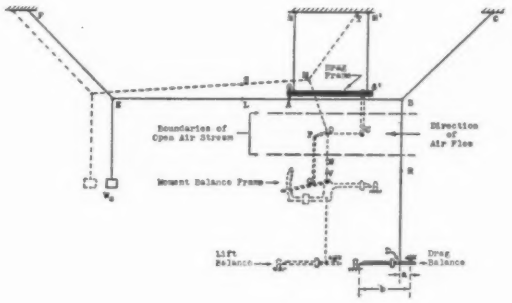

FIG. 1. Schematic diagram of aerodynamic balance arrangement.

are in the air stream. V-connections exist from A to L and from R to D. Spacers at B and R are made of wood dowel stock. Rigging requirements are that HG, H'G' and BRD wires be vertical, AB wires horizontal, and that the horizontal and vertical distances from B to C be equal. Turn buckles in all wire lines make this rigging process simple and, once made, the rigging can be checked by means of the relation of an index mark on the drag frame to the tip of a permanently suspended plumb-bob, not shown in the figure. In rigging, the system is balanced by varying the amount of the counter weight W_c.

The displacement of the drag balance rider necessary to bring the beam tip back to its index mark will be proportional to the drag force which caused the beam tip to move. (The drag balance was made by inverting a standard 35 lb. capacity Fairbanks balance. A drag force of 1 lb. corresponds to a rider displacement of nearly ten inches and the beam can be read directly, in decimal units, estimating to the nearest thousandth of a pound.)

Further, by less elementary mechanics, it is possible to evaluate the maximum possible sensitivity of this arrangement. If we define sensitivity (S) as the ratio of ϵ to Δ, where ϵ is the displacement of the tip of the drag balance beam caused by a change, Δ, of the drag force, D; and if we define W_c as the weight of the counter weight, W_f as the combined weight of drag frame and model assembly, and $\overline{BC}$, $\overline{EF}$, and $\overline{HG}$ as the lengths of the respective wires, then

$$\frac{1}{S}_{max.} = \left[\frac{\Delta}{\epsilon}\right]_{min.} = \frac{a}{b}\left[\frac{2\sqrt{2}(W_c+D)}{\overline{BC}} + \frac{2\sqrt{2}(W_c)}{\overline{EF}} + \frac{W_f}{\overline{HG}}\right]$$

This shows that sensitivity can be increased by decreasing weights and lengthening wires, and that the addition of the drag frame, which is a great practical convenience, need not be a serious factor in diminishing sensitivity. In the actual balance under discussion, a 25 cent piece applied at D or at We will cause the beam tip to move nearly 1/10 in., despite the fact that about 20 lbs. of material must be given finite displacement. The beam is equipped with an oil dash pot, and thus the rig is able to measure a drag force to within about 3/1000 lb., consistently.

That the set-up is rugged is proven by the fact that in seven years of continuous use it has never needed any attention. There is nothing that can be damaged, even by rough handling. The only expense worth mentioning is associated with the Fairbanks balance which, although of excellent construction, cost less than $25.

To show the adaptability of the drag frame, consider an "airfoil set-up." Referring now to the broken lines in Fig. 1, it will be necessary to explain that PQ is a light streamlined strut; at UG' are two struts which are not in the air stream; at MT, OM, and ON are double wires not in the same plane; at SM and NV are V-connections; at M and N are dowel spacer rods; PQ, ONV and the wire running to the lift balance are rigged to be vertical; wires OU are rigged to be horizontal; when the airfoil model is at zero angle of attack, the index of the moment balance is set at zero. Wires above the airfoil are permanently rigged. For these, any angles, roughly as shown, will do. A "sting" can be attached to the airfoil model, if desired, because an adjustment is provided at Q. The airfoil model is under no rigging stress because the connections at O are at the outer extremities of the leading edge. By adjusting the lift counterweight, to the left of We, and the position of the moment counter weight, directly below Q, the lift and moment beams can be brought to their indexes with riders set at zero.

Lift, drag and moment about O can be read directly and independently, for any angle of attack and air velocity, by noting the displacements of the riders necessary to bring the respective beam tips back to the index marks. Sensitivity is excellent. Little expense is involved in making up the moment balance, partly because of the absence of knife edges. The lift balance is a counterpart of the drag balance, the capacity of which can be extended to ten pounds or more by adding weights to a yoke just above D. Rigging can be executed quickly. Since there is nothing to get out of order, the device has never required any attention.

Further to illustrate the adaptability of the drag frame, consider a "model propeller" set up. A simple wood framework, carrying a small cradled motor which, mounted at the level of the drag frame, drives the model propeller shaft at the axis of the air stream, fits into the drag frame. No adjustments are required. The small motor is connected to an over-head outlet. V/ND is varied by varying the velocity of the air stream. Propeller torque is measured indirectly, but accurately, by the motor cradling device. Propeller rotative speed is measured by a home-made stroboscope mounted outside of the air stream. Propeller thrust is measured directly by the drag balance. No expense worth mentioning is involved in the whole device, and it is very simple and effective.

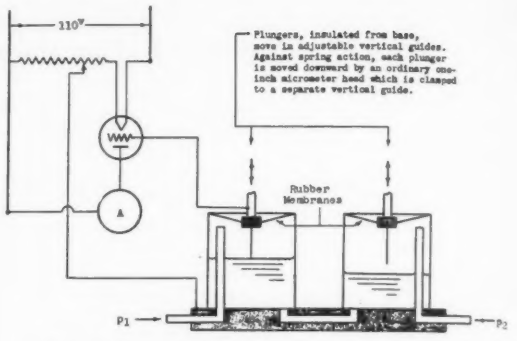
110V
Plungers, insulated from base, move in adjustable vertical guides. Against spring action, each plunger is moved downward by an ordinary one-inch micrometer head which is clamped to a separate vertical guide.
Rubber Membranes
A
P1
P2

FIG. 2. Schematic Diagram of Micromanometer.

Of the other adaptations of the drag frame which are possible, one of the most interesting is that used for testing rotating cylinders for Magnus effect. Space forbids describing this here.

Turning from the problem of measuring aerodynamic forces, let us consider briefly the other basic problem, namely, the measurement of pressures.

Pressures exceeding 3 inches of water can generally be measured by ordinary large bore water U-tubes. Most frequently, however, aerodynamic pressures encountered are less than this amount.

The laboratory has used standard laboratory-type Ellison draft gages (two Type 11440, 10 to 1 multiplication, capacity 1 inch of water, and two Type 11470, 5 to 1 multiplication, capacity 3 inches of water) with satisfaction. This battery of gages is mounted in such a way that each gage can be detached and used on its own portable base, if desired. Standard sizes of nipples, anti-pinch springs and tubing are used. It is difficult to injure these gages and their performance is much better than is popularly supposed. Although the error in an indicated reading may amount to as much as two per cent in extreme cases, it has been found that these gages give very consistent readings; that is, that the error calibration curve for a given gage will remain fixed for months. For accurate work, then, all that is required is to have some means of calibrating the battery of gages against a standard. Using parallel pressure connections, four or more gages can be calibrated almost as quickly as one, the operation requiring about three hours for careful execution. This leads to the discussion of the standard manometer, shown schematically in Fig. 2.

The instrument shown in Fig. 2 is based on the simple water U-tube principle, with glass wells of large bore (more than two inches) to reduce the error caused by capillary action. To determine the difference in levels of the two water surfaces, standard micrometer heads (one-inch capacity) are employed. So much is not new. To show when the needle point is just in contact with the water surface in a given well, use is made of the electrical circuit shown. Before the needle point touches the water, the resistance of the filament circuit of the vacuum tube is adjusted so that only a small current, perhaps 2 milliamperes, flows through the ammeter. At the instant of contact of needle point and water surface, the resistance of the grid circuit is reduced and the needle of the ammeter will jump sharply to a reading of, say, 10 milliamperes. Readings of the micrometer head, corresponding to contact conditions, can be duplicated consistently. This application of a familiar electrical circuit, to replace the optical devices usually associated with the sensitive manometer, was conceived and used, several years ago, by Leslie J. Hooper, of the Alden Hydraulic Laboratory. From him, the writer's associate, Ellis R. Spaulding, obtained permission to extend the application to the air manometer and subsequently designed and built the instrument to which Fig. 2 refers.

It is hoped that the foregoing discussion may be of service to those engaged in developing equipment for laboratory instruction in aerodynamics. If well developed, such equipment can be used in the performance of research work of technical importance. In support of this statement, the reader is referred to a paper entitled *"Research By Small-Scale Apparatus,"* by F. C. Johansen, Proceedings, I. Mech. E., March, 1929.

To the National Advisory Committee for Aeronautics, for furnishing aid in the design of the small wind tunnel mentioned, the writer wishes to express grateful acknowledgment.

Book Reviews

La Corrosion en Métallurgie; by GENERAL C. GRARD: Editions Berger-Levrault, Paris, 1936; 345 pages, ill., 50 francs.

This volume constitutes an excellent review of the latest scientific conception of the corrosion of metals, laying particular emphasis on metals in the aeronautic field. As nearly as possible within the space of one volume, there is a simple explanation of the chemical, electro-chemical, metallurgical, and engineering aspects of corrosion, without assuming any specialized knowledge on the part of the reader. It contains a bibliography which can be pursued by the specialist in whatever direction his curiosity, responsibility, or financial interest may lie.

The volume is divided into parts covering first principles—the structure of matter from the modern atomic point of view; an excellent discussion of ionsation and the behavior of electrolites; the modern use of *pH* measurement and the electrochemical behavior of electrolites in contact with metals. All this is clearly given in 47 pages, and is an achievement of the highest order.

The second part is devoted to the various phenomena of corrosion and the present day theories which account for the different types of corrosive attack. The part played by disturbances or variation of homogenous conditions is especially thoroughly considered, and the practical limitation in the attainment of such conditions is discussed for many metals, alloys, and corroding agents. A chapter of only 10 pages on activation and passivation treats this most important part of the corrosive phenomena in an extremely clear discussion.

The third part of the volume covers the different methods of protecting the important metals and alloys, particularly those used in the aeronautical industry. The type of corrosion of the important alloys and the type of protection used for various purposes is well covered but naturally in a limited way for each individual case. A number of volumes would be required to bring out the entire story on any one alloy, but a reference to the bibliography will show where the important publications on this subject can be found. In this connection it may be remarked that where possible, the bibliography refers to French rather than to foreign publications, but the bibliography on the corrosion of special materials is well covered in McKay & Washington's "Corrosion Resistance of Metals and Alloys," Am. Chem. Soc. Monograph.

The fourth part of the volume discusses the various varieties of corrosion tests, their uses, and their limitations. This is particularly important to all writing specifications in which the very difficult subject of corrosion is reduced to laboratory measurements. If this discussion of tests and specifications leaves anything to be desired, it is simply that there is at present no truly satisfactory method of making corrosion tests and apparently no hope of a simple system whereby comparable numerical results can always be obtained. In this chapter and throughout the book frequent mention has been made of negative results. This adds a great deal to the value of the volume in indicating the pitfalls that lie in wait for investigators in this field.

The volume draws attention to what I believe is a very important point, namely: that the French Air Ministry is assisted by the foremost metallurgical talent in France; that it maintains adequate research, and leads rather than follows. In this country I do not know of any comparable case in the field of metallurgy or strength of materials. Our Grade-A men in both fields are in private employment.

A. V. DE FOREST.

Technisches ABC der Luftwaffe, Parts 1 and 2; by VON HEILMANN; E. S. Mittler & Son, Berlin, 1936; 292 pages, ill., RM 2.80.

Part 1 of this elementary book for the enlisted men of the air force presents the mathematical principles and calculations used in aeronautics, the construction of simple diagrams, starting with the simpler mathematical figures and building up to more complicated forms, each step being accompanied with its proper proof.

Part 2 explains important physical laws, special consideration being given to the mechanics of solid bodies and the laws of falling bodies.

"Filled" Resins and Aircraft Construction

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(Received July 1, 1936)

SYNTHETIC Resins are of several kinds and are filled with various materials. The variety of physical properties which are obtainable from them is, therefore, great. They have not yet been developed to any extent as possible structural materials, but owing to their many valuable properties it is worth while to see what position they occupy from this point of view.

The strength/weight ratios of steel, light alloys and spruce are all about the same, and any new material must roughly conform in this respect to qualify as a constructional material.

The elastic modulus is the next important criterion since it determines the ratio of length to radius of gyration which must be employed in compression members in order that the full compressive strength of the material may be developed. Since the elastic modulus defines the amount of strain under load it therefore determines the deflection of a complete structure. This, however, is not the whole story, as will be seen from the fact that a spruce and steel wing (for the same conditions of loading, depth, etc.) suffer the same deflection while steel has an elastic modulus twenty times as great as spruce. This is merely because the compressive strength which has to be developed by the steel is also twenty times as great, and thus these two characteristics cancel out.

The ratio of elastic modulus to stress developed fixes two important characteristics, first the deflection of the structure under load, and second the radius of gyration which must be provided in cross-sections to avoid Euler strut conditions.

Steel, Duralumin and Spruce are all about equal in this respect, and have approximately similar strength/weight ratios. They are, therefore, equally suitable materials so far as the prime physical properties are concerned.

There is one important point to be remembered here. Of materials of equal suitability as defined before, those of lower specific gravity will, owing to their greater bulk, require fewer artifices for securing the rigidity necessary to develop their full strength.

The two criteria mentioned before are shown for various materials in Table 1.

Synthetic resins may be examined with various fillers in the light of these considerations. An ordinary fabric filled insulating material has roughly the properties shown in Table 2.

Since the ordinary material weighs about three times as much as spruce and is no stronger in tension it might be dismissed immediately as an aircraft material. There are, however, many reasons for pursuing the matter further. These filled resins somewhat resemble wood in their behaviour under fatigue, they absorb vibration, are good under impact, are virtually uncorrodible and take a fine finish. Furthermore, it is well known that vegetable fibres possess great strength and light weight. They can be obtained today with a strength/weight ratio of about 17×10^5 in the form of artificial silk, cotton and many other fibres. This is much better than any known metal, and about three times that for spruce. It seemed likely that an aggregate in which such fibres were more rationally disposed for strength might provide an improvement on the ordinary product.

A first experiment in this direction gave the results shown in the second column in Table 2. This is such a substantial improvement that it gives considerable hope for the future. It will be noted, however, that the elastic modulus is still much too low. The early work done in America by Caldwell also pointed in the same direction.

The other criterion mentioned before, namely the ratio of elastic modulus to stress developed is lower than in other aircraft materials and this means that it is not yet a suitable material for aircraft construction. To bring the fabric filled resins into line with steel, duralumin and spruce, it would be necessary that the elastic modulus is raised to something approximating to 5×10^6.

TABLE 1

	Ratio of Strength .. lbs./sq. inch to Wt.. .lbs./ cu. inch.	Ratio of Young's Modulus to Strength.. .lbs./ sq. inch.
Steel (90,000 lbs. ult.).....	3.2×10^5	343
Steel (135,000 lbs. ult.)	4.8×10^5	228
Dural (50,000 lbs. ult.).....	4.8×10^5	212
Spruce (8,000 lbs. transverse)	5.0×10^5	190

TABLE 2

	Ordinary fabric filled phenol resin.	Improved fabric filler.
Ultimate Tensile Strength..	11,000 lbs./sq. inch.	27,000 lbs./sq. inch.
Compressive Strength..	25,000 lbs./sq. inch.	27,000 lbs./sq. inch.
Shear Strength.....	4,000 to 7,000 lbs./sq. inch.	6,000 to 7,000 lbs./sq. inch.
Young's Modulus.....	1.1×10^6	$1.8. \times 10^6$
Specific Gravity.....	1.4	1.4
Strength/Weight.....	1.4×10^5	3.4×10^5
E/Strength.....	109	75
Impact.....	3 to 7	32 to 37

Alternatively, if the material could be reduced in specific gravity to about half its present value, while retaining the same elastic modulus, the strength could be reduced in the same ratio, and it would become a suitable aircraft material.

It has been found that the nature and arrangement of the filler primarily determines some of the physical properties of these resins. An ordinary woven fabric is by no means the most suitable filler as it permits "creep" to take place at too low a stress and gives a low elastic modulus. This might be expected from the disposition of the fibres. It may be noted that the fibres in trees are well arranged to take compression, although they are weakly cemented together. Very useful materials may, however, be obtained by compressing and "bakelising" wood. The results in Table 3 were recently obtained on specimens submitted by a manufacturer of this kind of material. It was compressed, laminated, bakelised Beech.

TABLE 3

Transverse strength (modulus of rupture)	37,000 to 41,000 lbs./sq. inch.
Young's Modulus	3.85–4.58 x 10^6 lbs./sq. inch.
Shear strength	2,550–3,000 lbs./sq. inch.
Specific gravity	1.3–1.4.

The low shear strength is a feature of wood and is due no doubt to the fact that the fibres are more loosely cemented together than in synthetic filled resins.

From numerous experiments it has been found that there are considerable possibilities of favorable development and it appears well worth pursuing the matter further since a very small portion of the inherent properties of cellulose fibres has been yet realised.

The difficult but important question of making efficient joints can perhaps be left until further progress has been made in the material.

So far propellers have not been mentioned. The use of synthetic resins for this purpose has been going on sporadically for twenty years or so, most of the early development being due to Caldwell. It is perhaps rather surprising that they have not been more extensively used. Now that high duty and controllable pitch are called for, the advantages of fabric filled resins stand out very strongly. In addition to the valuable properties already mentioned these materials possess a plasticity which prevents local concentrations of stress, and the material is well suited to form heavily loaded bearings. The low elastic modulus does not matter much in a propeller since it is mainly under tension and is tending to maintain itself more or less in the plane of rotation. It does, however, lead to the use of thicker sections as a precaution against blade flutter.

A controllable pitch propeller with blades machined from blocks of standard fabric filled Bakelite insulating material has been undergoing thorough flight trials recently. This propeller is mounted on the ordinary Hamilton type of hub with, of course, a more generous area in shear at the root than is required for Duralumin blades. The centrifugal thrust is taken on a split roller bearing, and the spider which imparts the driving torque and upon which the pitch-change rotation takes place bears directly in the Bakelite which seems well suited to this arduous duty.

This propeller has been submitted to very severe back-firing and slow-running-with-one-cylinder-out tests as well as the usual overload tests. It is entirely satisfactory.

The object of this note is to draw attention to the possibilities of development of these materials rather than to present results of what has been already achieved, for very little ground has yet been covered. It would seem likely that synthetic resins may one day play an important part in aircraft construction. The limitations of what is now available have been indicated and may be summed up by saying that the elastic modulus is too low in relation to the stress which must be developed if a proper return is to be obtained from the weight of the material.

The Field of the Large Commercial Airship

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THE recent demonstration flights of the "Hindenburg" have revived American discussion of the merits of commercial airships. Since the discussion seems now to have moved from the popular literature into technical publications, it appears desirable to bring before aeronautical engineers the technical fundamentals underlying the situation. This article is offered in an attempt to clarify the respective merits of various types of aircraft and to show that they may efficiently be fitted into a world-wide transportation system.

Speed is, of course, the accepted advantage of air travel over surface transportation. In order to assure patronage overland, aircraft must exceed by a sufficient margin the speed of the automobile and the train and must make up for the time lost between an airport and the heart of a city. The actual speed based on elapsed time between points of departure and destination depends greatly on the time lost in intermediate stops. A compromise must be attained between the delay of intermediate landings and the economic advantages of reasonably frequent stops for refueling and crew relief. The longer the individual non-stop distance the more the fuel load encroaches upon the payload. In order to attain the maximum ton-miles of payload carried by any aircraft a certain ratio of payload to fuel load is most advantageous. For most overland and coastal routes it is possible to select airplanes that can operate over the required non-stop distances of say 1000 miles or less under conditions approaching these best ratios and hence with a desirable economy.

For transoceanic flights, however, the situation is different. The transatlantic distance to Europe non-stop is of the order of 4000 miles. With intermediate stops such as Bermuda and the Azores, open stretches of ocean to be crossed are of the order of 2000 miles. Across the Pacific to the Orient the necessary non-stop distance is even greater. To take off with the fuel necessary to cover such distances, airplanes must sacrifice payload until the ratio of payload to fuel load is unfavorable. Therefore, across oceans these airplanes must operate much less economically than over land.

Flying boats, not being limited for take-off by the size of existing airports, can be made to carry an additional payload obtained at the penalty of take-off run. With very high wing loading and high power loading in lbs. per hp. such a flying boat requires a great body of protected water where it can take off with what amounts to a virtual overload. This could explain why the flying boat figures usually published seem to include a payload superior to that of land planes in transport service.

Under the conditions of best lift/drag ratio, best propeller efficiency and best specific fuel economy, the airplane (as well as the airship) would yield a corresponding maximum conveyance output in ton-miles payload carried when the initial ratio of payload to fuel load is approximately governed by the transcendental equation

$$p = (W_2/W_1) \log_e (W_2/W_1),$$

where $p =$ payload/gross lift, $W_1 =$ take-off weight, and $W_2 =$ landing weight. For airplanes capable of taking off with a useful load (including service load of 4% of gross lift) approximately equal to their own dead weight, the best fuel load from this standpoint would be about 1.15 times the payload carried. So loaded, an airplane having a best lift/drag ratio of say 12, with conventional engines and with a propeller efficiency in the neighborhood of 80% would have a theoretical maximum Bréguet range of the order of 2200 miles. To traverse a greater distance or to carry spare fuel, payload must be sacrificed more than in proportion to the potential gain in range. In order to fly at the angle of attack of this best lift/drag ratio of 12 to 1, the airplane must cruise at reduced speed and power. If it were to make use in transit of all the power it has and needed for the take-off, it would have to fly in the stratosphere. However, high head winds there may frustrate the advantage of the lesser density. As long as commercial airplanes fly at moderate altitudes their economical speed remains comparatively low, say 120 m.p.h. at 7000 feet; otherwise they cannot utilize their best lift/drag ratio. Under normal operating conditions the effective range of the craft is generally less than the Bréguet equation would give for the combination of the best values of the variables entering into it.

The lift/drag ratio of airplanes is less sensitive to speed than that of airships. This will tend to benefit the airplane in cases where high speeds are found desirable. On the other hand, if relatively low speed aircraft will satisfy transoceanic air traffic requirements, the airplane can benefit little by flying slow. For moderate speeds, therefore, the airship reaps the greater benefits.

On the transoceanic routes these moderate speeds may well be economically sound. On these routes there is no competition from high speed trains. The fastest surface vessels operate at sustained sea speeds below 30 knots. Any new means of transportation crossing at twice this speed would offer such a substantial saving of time as to assure patronage. Any further increase of speed (at whatever cost) could not possibly offer again as large a time advantage. A saving of 2½ to 3 days on a 5 day journey from continent to continent should be so appreciated by business and travelers that a legitimate need for still higher speed would probably arise only from a relatively small portion of the traffic willing to pay extra for it.

In the minds of those unfamiliar with airship engineering, the mistaken idea prevails that airships with their "enormous bulk" must be very inefficient in drag. The contrary is the case. The larger the ship, the better is its ratio of lift to drag. The carrying capacity increases with the third power of the linear dimensions, but the drag of a shape of given drag coefficient increases only with the square. Besides, the drag of the hull being almost entirely skin friction and protuberances not increasing in proportion to the size of the hull, the drag coefficient of the airship itself diminishes with increasing size.

The gross lift per unit drag area of a large rigid airship is about 700 lbs./sq. ft., or of the same order as that of a large flying boat. The airplane consumes a large amount of fuel either for high speed or for the induced drag which increases when speed is reduced. The airship, however, carries its load independently of speed and thus can fly as slow as the requirements of a sufficient speed advantage over existing modes of transportation dictate and, therefore, the fuel load can be kept much lower in proportion.

The potential range of an airplane or flying boat is expressed by Bréguet's equation[1]

$$x = (C_L/C_D)\ (\eta/c)\ \log_e\ (W_1/W_2)$$

in consistent units, (or, times 375 for miles and lbs./hp. hr. units); where C_L and C_D are the lift and drag coefficient, η the propeller efficiency and c the specific fuel consumption.

The potential range of an airship can, under certain assumptions[2] be expressed by a formula closely paralleling Bréguet's, viz:

$$x = (V^{\frac{1}{3}}\beta/q\ C_D)\ (\eta/c)\ \log_e\ (W_1/W_2)$$

where V is the displaced volume, β the buoyancy of the gas in the displaced air and q the velocity head. The analogy between the two equations becomes evident when one considers that $V\beta$ is the static lift L of the airship while $C_D V^{\frac{2}{3}} q$ is the drag D so that $(V^{\frac{1}{3}}\beta/qC_D) = L/D$.

The first factor shows how for any given values of C_D, η/c, and W_1/W_2 the potential range of an airship would increase linearly with size ($V^{\frac{1}{3}}$) but drop inversely proportional with the square of speed (q), while that of the airplane would stay unaffected by the choice of either.

In reality, any change of size or speed would also affect the dead weight of the craft and thereby the ratio W_1/W_2 which governs the best ratio p of payload to gross weight. For the airplane the ratio of useful lift to gross lift seems to vary but little with size and speed under present day strength requirements; it is of the order of ½. For modern trans-oceanic airships, similar values prevail. For the airship, from the standpoint of present strength requirements, the ratio of dead weight to gross lift tends to diminish with size. However, there is an influence of speed on airship dead weights. The power plant weights are affected by less than the third power.[3] Certain structural parts would have to be increased in strength at the rate of the square of the speed, others linearly with speed. (The weights of these parts would increase less than in proportion to their strength.) Many other parts would stay unaffected by a change in speed. The grand average of the dead weight increase may be estimated to be between the first and 1.25th power for reasonable increase of speeds. If this power were the 1.25th, for instance, then the airship's conveyance output in ton-miles payload would vary approximately inversely with the third power of air speed. For the flying boats, in the regime of smaller angles of attack, in which they actually fly, the corresponding value varies more nearly at a rate inversely proportional to the first power of speed.

The difference between these exponents indicates how, if a definite speed were postulated, the airplane is at an advantage when this speed is high, and the airship when this speed is moderate. Exact comparisons depend upon design details and the distance to be crossed. The longer the distance, or the slower the acceptable speed, the greater the advantage of the airship.

In order to compare actual figures an airship and a flying boat both comparable with the most highly developed contemporary designs were assumed. (See Table I.)

[1] cf. L. V. Kerber, *Airplane Performance*, Div. O, Vol. V, Aerodynamic Theory by W. F. Durand, 1935.

[2] viz., assuming that the gradual consumption of fuel is turned to advantage by climbing to altitude of lesser density. If this were not done, as was the case with such airships as did not valve, or if headwinds aloft would frustrate the advantage, the range with a fuel load F is simply $x_o = F\eta/cD$ and the best ratio of fuel load to payload is one to one. Cf. Arnstein ASME Transactions, Jan.–Apr. 1928. The difference in range may be of the order of 10% for a 5000 mile trip and less for shorter distances.

[3] Airship engines have been much heavier per hp. than contemporary airplane engines. This was conducive to added safety, reliability and longer overhaul intervals. If more engines were provided for higher speed, there would be added safety in the greater number and no reason why the lighter specific weight of airplane engines could not be approached. In this case the weight increase could be very much less than at the rate of the third power.

TABLE I

Airship — Flying Boat Comparisons *

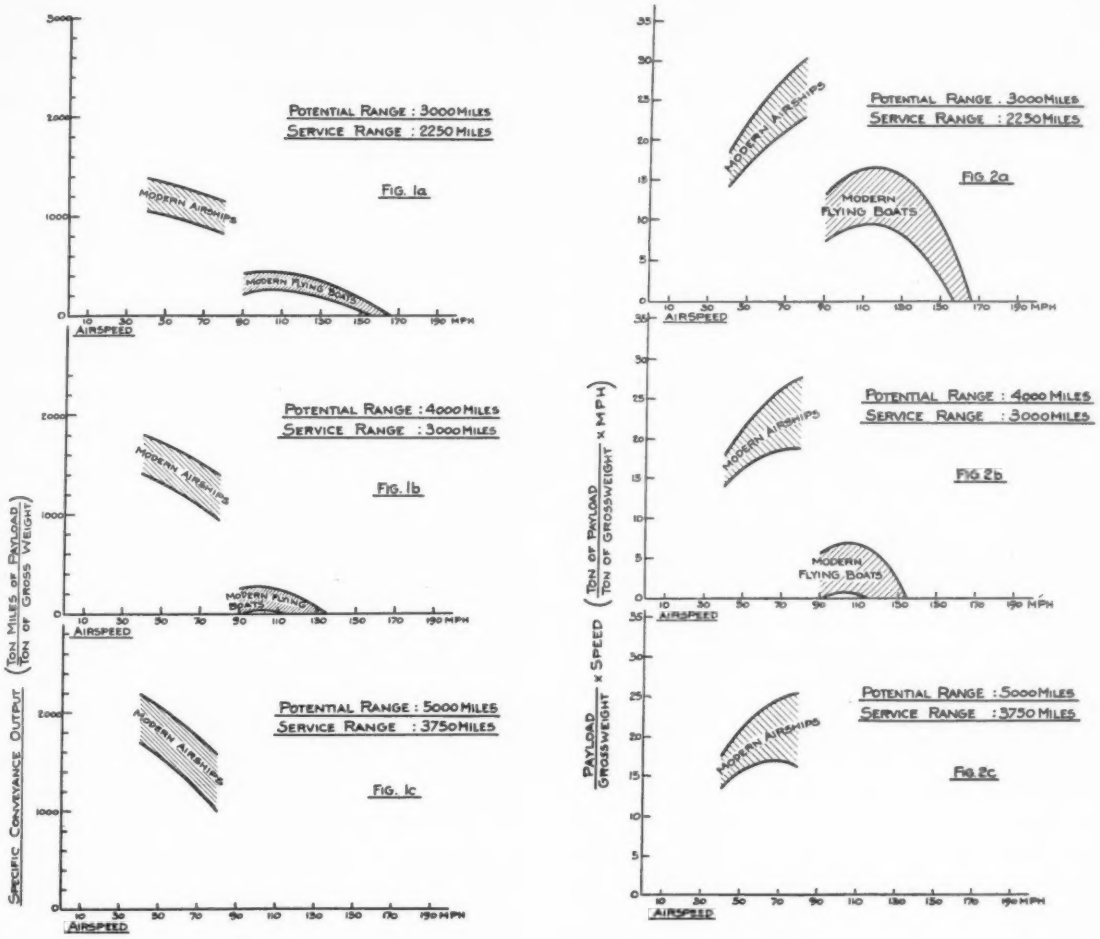
	Airship			*Flying Boat*			*Units*
Gross lift (L)	509,000			51,000			lbs.
Useful load	273,600			26,400			"
% useful load	53.5			51.8			%
Parasite drag area	760			68			sq. ft.
Power	4400			3320			hp.
Spec. fuel & oil consumption (c)	.407			.48			lbs./hp. hr.
Propeller efficiency (η.)	.71			.80			
Lift/Drag (L/D)	55 (At cruising)			12.2 (best)			
Service range	2250	3000	3750	2250	3000	3750	Miles
Range in still air	3000	4000	5000	3000	4000	5000	Miles
A.) *At low speed*	50	50	50	102	99.2		m.p.h.
Lift/Drag	108	108	107.5	12.2	12.2		
Payload	113	110	106.5	3.84	1.77		tons
Fuel load	10.7	14.2	17.6	8.36	10.43		tons
Ton-miles of payload	340,000	440,000	532,000	11,500	7,060		ton-miles
Ratio payload/fuel load	10.6	7.74	6.05	.46	.17		
Fuel per mile	7.13	7.10	7.04	5.57	5.22		lbs.
Fuel per ton-mile of payload	.0530	.0646	.0661	1.45	2.95		lbs.
B.) *At cruising speed*	70	70	70	126	122		m.p.h.
Lift/Drag	55	55	55	11.5	11.5		
Payload	104	97	90.8	3.24	1.08		tons
Fuel load	20.6	27.1	33.3	8.96	11.12		tons
Ton-miles of payload	310,000	388,000	454,000	9,720	4,340		ton-miles
Ratio payload/fuel load	5.02	3.58	2.72	.36	.097		
Fuel per mile	13.7	13.6	13.3	5.97	5.56		lbs.
Fuel per ton-mile of payload	.133	.140	.147	1.84	5.18		lbs.
C.) *At top speed*	85	85	85	166	136		m.p.h.
Lift/Drag	37	37	37	——	——		
Payload	94.3	85.2	76.5	0	0		tons
Fuel load	29.8	38.9	47.6	12.8	12.8		tons
Ton-miles of payload	283,000	341,000	383,000	0	0		ton-miles
Ratio payload/fuel load	3.16	2.19	1.61	0	0		
Fuel per mile	19.9	19.5	19.0	8.53	6.40		lbs.
Fuel per ton-mile of payload	.211	.228	.249	——	——		lbs.

Not Within Range

* Where authentic or consistent values have not been available we have made our own estimates. The speed given is the actual speed of the airship throughout the whole trip. For the flying boat it is more advantageous to fly at the highest possible $C_L\ C_D$ value. The speed given is therefore the average speed at 7000 feet altitude. Propeller efficiency and fuel consumption figures for the airship are actual figures obtained as an average of many flights. The flying boat figures were assumed to be the average of the whole trip. Since the distances were computed with the full Bréquet range without using reductions it is believed that the flying boat performance given is rather favorable. For the flying boat a service load of 2000 lbs. or less than 4% of the gross weight was assumed while for the airship a service load of about 25,000 lbs. or about 5% of the gross lift was used.

This table shows how rapidly the picture changes with range if payload-miles are taken as a measure of merit.

In order to show the influence of speed on the specific conveyance output in ten-miles of payload per ton gross weight for the two types of carriers, Figs. 1a to 1c were prepared. These charts show the specific conveyance output against air-speed for various ranges. For reasons of simplicity the conveyance output was based on the potential (Bréguet) range in still air but it should be noted that the actual operating distance (service range) would conceivably be about 75% of this theoretical range in order to have adequate fuel reserves aboard. The operating ranges of both the airship and the flying boat are represented by shaded areas. The upper boundaries of these areas contain the values given in Table 1. The upper airship curve refers to a modern airship inflated with hydrogen and equipped primarily as a mail and freight carrier; the lower curve would apply to helium inflation. The upper flying boat curve refers to the best published data of existing flying boats, which are also taken as not to comprise passenger accommodation weights. The airship curves were based on actual flight experience as to fuel consumption and efficiency for various air-speeds, which were assumed held constant thruout the trip. Since the optimum airplane speed varies during


SPECIFIC CONVEYANCE OUTPUT (TON MILES OF PAYLOAD / TON OF GROSS WEIGHT)
POTENTIAL RANGE : 3000 MILES
SERVICE RANGE : 2250 MILES
FIG. 1a
MODERN AIRSHIPS
MODERN FLYING BOATS
AIRSPEED
POTENTIAL RANGE : 4000 MILES
SERVICE RANGE : 3000 MILES
FIG. 1b
POTENTIAL RANGE : 5000 MILES
SERVICE RANGE : 3750 MILES
FIG. 1c
PAYLOAD / GROSSWEIGHT × SPEED (TON OF PAYLOAD / TON OF GROSSWEIGHT × M.P.H.)
FIG 2a
FIG 2b
FIG 2c

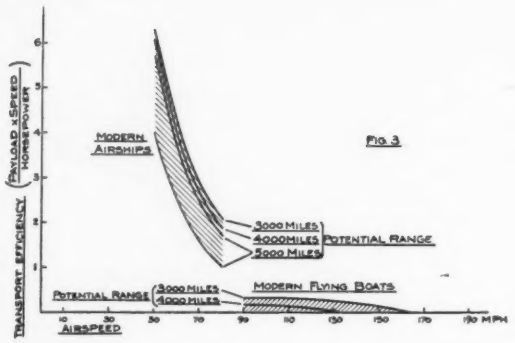
the journey, the values were plotted against mean airspeed.

As can be seen from these curves, the specific conveyance output of airships even for the smallest range under consideration is more than twice as large as that of flying boats and is still improving for larger ranges, while that of flying boats decreases and at a service range of 3750 miles is already zero. It may also be of interest to note that with these larger ranges the flying boat has to fly slower in order to cover the distance at all.

Now it must be admitted that even if an economical speed is satisfactory from the traveler's standpoint, greater speed does have a bearing on the utilization of the initial investment. Those who wish to emphasize this fact and who feel that increases in speed may command proportionately higher tariffs have suggested the product of speed by tons of payload per unit gross lift as a merit figure. It would seem that this overestimates the value of extra speed.

For example, there is the matter of fuel cost. An airship flying at 75 m.p.h. needs only about a tenth of the fuel per ton-mile payload as compared to a flying boat flying at 4/3 the speed over the same range of 3000 miles. The lower fuel consumption is doubly valuable for the operator when one considers that engine repair and maintenance cost, which are large factors in the total transportational cost, are also approximately proportional to the amount of fuel used and when one further considers that for this relatively low fuel consumption an airship could carry about 25 times the payload on a 2250 mile route and about 50 times the flying boat's payload over a distance of 3000 miles.

Therefore, this merit figure which is directly proportional with speed must be looked upon as already containing a speed premium, if it is to be applied for comparisons of airships and flying boats. Figs. 2a to 2c will give a comparison of the various craft for the product of speed by tons payload per unit gross lift. Again the advantage of the airship over great distances can be clearly distinguished. It must not be forgotten that although the flying boat is capable of a high top speed, roughly twice that of the airship, the economical speed for most efficient long range operation of such a



flying boat is very much lower, of the order of ⅔ the top speed when fully loaded as for take-off, and but one-half the top speed towards the end of the journey. Appreciation of these facts greatly diminishes the often over-emphasized inherent difference in air speed between lighter and heavier-than-air craft.

Of course the non-stop distance across the oceans can be reduced by intermediate refueling stops at natural and artificial islands. However, one would not be justified in directly comparing the flying boat curve of Fig. 2a with the airship Fig. 2c without allowing for these stops and the necessarily devious routes. The effective speed in transit over the North Atlantic would be reduced to, say 60% of the flying speed; this percentage reduction would apply to the ordinates of Fig. 2a for the flying boat. Therefore, if one compares the modern airship, operated non-stop between New York and Paris (3750 miles) with a flying boat covering the distance by the circuitous route Bermuda-Azores with several intermediate stops, it will be found that the specific payload times speed of the airship is still more than twice as great as that of the flying boat.

A more convincing standard of comparison is afforded by the quantity Payload × Speed / Engine Power which may be looked upon as a measure of "transport efficiency." [4] This quantity is plotted for both types of craft on Fig. 3. It shows the airship many times superior to the flying boat from this standpoint. The value put on speed in this presentation is governed by efficiency considerations rather than by speed premium considerations.

Studies have shown that transoceanic air traffic (passenger, mail, express and freight) should be ready to pay for safe and regular service; however, the question is how much of a premium can be expected for higher speed. Transoceanic aircraft will attract much new traffic but airships by virtue of their comfort and spaciousness, comparable to luxurious sea-going vessels, safety of service and bulk of capacity, will attract a certain amount of traffic that would be reluctant to go by airplane. If we neglect the influence of these unquestionable advantages of the airship in attracting business, there still remains the advantage of the comparatively low cost of transportational service for the short "time in transit" by which the customer judges the service. Because of the necessity of intermediate stops and layovers and their indirect routes, the present day flying boat services in spite of their higher top speed offer the passenger little or no saving in elapsed time as against the airship flying on a direct route.

When the time comes when commercial airplanes are capable of crossing the Atlantic on the great circle course without intermediate stops, the traveler will have the choice of three carriers:

(1) Steamships which permit passengers to travel from an American terminal to a European terminal in as little as 5 days.

(2) Airships capable of cutting the fastest of these crossing times in half.

(3) Flying boats with which one would hope to save still another day.

Now consider the transportional expense involved in terms of cost per ton of payload moved. The indirect operating expenses (traffic solicitation, flight insurance, etc.) need not be any higher for the airship than for the airplane on a unit cargo basis. For similar rates of equipment write-off, the annual depreciation charges are determined by the amount of capital invested in flying equipment. It has already been indicated that the airship offers a greater carrying capacity per ton of flight equipment used than the airplane. Since both types of aircraft have comparable cost per unit of dead weight, the airship offers greater payload capacity for the same investment. The capital investment for airship terminals may appear high but it is not out of line in view of the large payload handled particularly as soon as the equipment is used by more than one airship. Recent refinements of mast equipment have proved so practical in actual use that docking facilities need not necessarily be considered for both terminals of a transatlantic line.

Items connected with direct operating costs are susceptible to comparison in the same way, and the airship compares well with large flying boats for long range operations. While an airship flight crew is numerically large, the requirement is about one or two men per ton of payload as against four to six men per ton of payload in the case of the modern long range flying boats. The fuel economy has already been discussed and it has been shown that airships are much more efficient than airplanes when it comes to fuel consumption per ton-mile of payload carried. The advantage of the airship in this respect is inherent to the obtaining of lift without paying the penalty of induced drag. In all fairness to the airplane it must be stated that relative fuel costs do not determine operating costs unless one includes in the airship fuel

[4] W. F. Durand, *Aerodynamic Theory*, Vol. VI, Chapter RII, Section 6, 1936.

cost an additional allowance for expenses connected with valving hydrogen. On this basis the combined fuel and gas cost for the airship per ton-mile is still only between a fifth and a tenth of that of the flying boat.

A word should be added about the future. With larger flying boats, larger payloads may become possible, but the capital and operating charges must be expected to grow apace. Furthermore, airship development cannot lag forever. The modern airship, although a wonderful vehicle as it stands, is capable of considerable improvement.

Both craft will equally benefit from future improvements of propellor efficiency, fuel economy and structural materials. As to aerodynamic refinement, hardly anybody can foretell what one shall yet learn. Viewed in the light of past history one might expect that systematic research may open up avenues towards reduction of skin friction just as induced drag and parasite drag of protuberances have already been combatted. As to higher speeds in the future, airship proponents recognizing the natural advantages of their type of aircraft will not attempt to attain airplane speeds merely by crowding more power into their ships. Progress will be sought mostly through design refinement and already appreciable increases in cruising speed are in sight without resorting to over-powering.

Since the airship has no difficulty in providing for a sufficient range at a meritorious speed, and since its range increases when slowing down, it has the benefit of an inherent element of safety or assurance of reaching its destination in the face of adverse circumstances. By slowing down, it can make up for abnormal consumption of fuel and is still able to reach port. Thus while an emergency may encroach upon its speed advantage over the existing means of surface transportation and arrival may be delayed, the passengers and crew need not be in danger. Surface vessels also suffer occasional delays due to adverse weather and tide. Airplanes may be grounded by fog and forced down by ice formation. The airship is not hampered by fog and is less affected by ice formation.

Transoceanic airship service naturally stimulates airplane travel. Feeder service by airplane is already a necessity and a commercial airplane hook-on arrangement is now actually available on the "Hindenburg." During the "Hindenburg's" first lay-over at Lakehurst, nearly 600 persons traveled by airplane to and from the airship terminal. Of the 50 airship passengers who crossed the ocean on the "Hindenburg's" first trip to North America, 37 went on to Newark by airplane and 42 of the 48 east-bound passengers went to Lakehurst by air to embark on the "Hindenburg."

How then, do the airplane and airship fit together into the transportational picture? In the first place the airplane is accepted and unchallenged for short and medium length overland and coastal services. For long non-stop flights of say 2000 miles and upwards the flying boat is a more expensive carrier than the airship but it admittedly has prospects for higher speeds than are expected of airships. The question as to whether or not the higher speed of these future airplane services will be alluring enough to attract traffic at the necessarily higher rates is one which time alone can answer. This much, however, is clear: that if it is possible for transoceanic flying boat lines to attract this traffic at their higher rates, the airship is assured of a full and gratifying patronage for its somewhat slower but appreciably cheaper transportation. Airship proponents believe that when that time comes there will be traffic enough for both types of aircraft and that they will be found to offer distinctly different and supplementary types of service. In the meantime the airship stands available as the only type of aircraft which has proved its capability to carry mail, passengers and freight on a commercial basis over any ocean in the world.

Tapered Bean Column Analysis for Uniformly Distributed Loads

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STRUCTURES in which the strength to weight ratio must be as high as possible are frequently built using tapered members which are subjected to both axial and transverse loads even though an exact method of analysis of members of this type has not been available and approximate methods of analysis are quite unsatisfactory. If the moment of inertia can be expressed by an algebraic monomial, this problem can be solved for a uniformly distributed transverse load and a compressive axial load in terms of Bessel functions and rapidly convergent series. In several particular cases more simple solutions are possible.

If, as in Fig. 1, we have a tapered beam with end moments, a compressive axial load, a uniformly distributed transverse load, and a moment of inertia which, with respect to the coordinate system used in this analysis, can be expressed as an algebraic monomial, the bending moment at any point on the beam is

$$M = M_1 + \frac{M_2 - M_1}{L}(x - x_1) - \tfrac{1}{2}wL(x - x_1) + \tfrac{1}{2}w(x - x_1)^2 - Py$$

Differentiated twice with respect to x this becomes

$$d^2M/dx^2 = w - P(d^2y/dx^2),$$

as, in accordance with the common theory of flexure,

$$d^2y/dx^2 = M/EI = M/Ekx^n$$

the differential equation of the bending moment may be rewritten

$$d^2M/dx^2 + (P/Ek)(M/x^n) = w$$

By making the substitution

$$z = \frac{2bx^{1-\frac{n}{2}}}{2-n}, \text{ where } b = (P/Ek)^{\frac{1}{2}},$$

which is valid as long as n is different from 2, the equation is transformed to

$$\frac{d^2M}{dz^2} - \frac{n}{2-n}\cdot\frac{1}{z}\cdot\frac{dM}{dz} + M = \frac{w}{b^2}\left[\frac{(2-n)z}{2b}\right]^{\frac{2n}{2-n}}$$

It is apparent that this is a Bessel type equation. The solution when

$$n \neq o \text{ or } 2, \text{ and } 1/(2-n) \neq o, \pm 1, \pm 2, \ldots \text{ is}$$

$$M = Vz^{\frac{1}{2-n}}J_{\frac{1}{2-n}}(z) + Wz^{\frac{1}{2-n}}J_{\frac{1}{n-2}}(z)$$

where

$$V = \frac{w}{b^2}\left[\frac{2-n}{2b}\right]^{\frac{2n}{2-n}}\frac{\pi}{2\sin\left(\frac{\pi}{2-n}\right)}\int^z z^{\frac{n+1}{2-n}}J_{\frac{1}{n-2}}(z)\,dz$$

$$W = -\frac{w}{b^2}\left[\frac{2-m}{2b}\right]^{\frac{2n}{2-n}}\frac{\pi}{2\sin\left(\frac{\pi}{2-n}\right)}\int^z z^{\frac{n-1}{2-n}}J_{\frac{1}{2-n}}(z)\,dz$$

The expressions for V and W are in general non-integrable and must be solved by expansion in series and term by term integration. The final equations are then

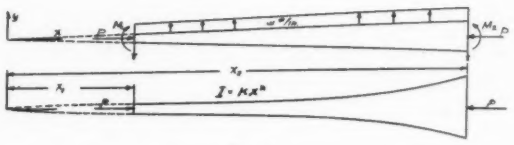

FIG 1.

$$V = wb^{\frac{4}{n-2}}\cdot\frac{\pi}{\sin\left(\frac{\pi}{2-n}\right)}\cdot\frac{(2-n)^{\frac{2n}{2-n}}}{2^{\frac{1}{2-n}}}\cdot\left(\frac{1}{2}z\right)^{\frac{2}{2-n}}$$

$$\times\sum_{r=o}^{\infty}\frac{(-1)^r}{r!}\cdot\frac{\left(\frac{1}{2}z\right)^{2r}}{\left(\frac{1}{2-n}+r\right)\Gamma\left(\frac{1-n}{2-n}+r\right)} + C_1$$

$$W = -wb^{\frac{4}{n-2}}\cdot\frac{\pi}{\sin\left(\frac{\pi}{2-n}\right)}\cdot\frac{(2-n)^{\frac{2n}{2-n}}}{2^{\frac{1}{2-n}}}\cdot\left(\frac{1}{2}z\right)^{\frac{4}{n-2}}$$

$$\times\sum_{r=o}^{\infty}\frac{(-1)^r}{r!}\cdot\frac{\left(\frac{1}{2}z\right)^{2r}}{\left(\frac{2}{2-n}+r\right)\Gamma\left(\frac{3-n}{2-n}+r\right)} + C_2$$

For the cases excluded from the preceding solution when $1/(2-n)$ is integral, the solution is similar and is as follows:

$$M = Tz^{\frac{1}{2-n}}J_{\frac{1}{2-n}}(z) + Uz^{\frac{1}{2-n}}Y_{\frac{1}{2-n}}(z)$$

where

$$T = -\frac{w}{b^2}\left[\frac{2-n}{2b}\right]^{\frac{2n}{2-n}}\cdot\frac{\pi}{2}\int^z z^{\frac{n+1}{2-n}}Y_{\frac{1}{2-n}}(z)dz$$

$$U = \frac{w}{b^2}\left[\frac{2-n}{2b}\right]^{\frac{2n}{2-n}}\cdot\frac{\pi}{2}\int^z z^{\frac{n+1}{2-n}}J_{\frac{1}{2-n}}(z)dz$$

These expressions are non-integrable when $1/(2-n)$ is negative and would be solved by expansion in series and term by term integration; however, as the series for $Y_{\frac{1}{2-n}}(z)$ is very complex, this solution is not practical. This difficulty may be avoided by taking a value of n which will not make $1/(2-n)$ a negative integer; for example, if n equals 3, $1/(2-n)$ is -1, and the solution involving the series for $Y_{\frac{1}{2-n}}(z)$ should be used; but by taking n equal to 3.001, $1/(2-n)$ is $-.999$; and the general solution may be used. The error involved would be negligible.

When $1/(2-n)$ is a positive integer, the expressions for T and U are always integrable. The most important case occurs when n is 1. In this case,

$$T = -\frac{\pi w}{8b^4}\int^z z^2 Y_1(z)\,dz$$

$$= -\frac{\pi w}{8b^4} z^2 Y_2(z) + C_1$$

$$U = \frac{\pi w}{8b^4}\int^z z^2 J_1(z)\,dz$$

$$= \frac{\pi w}{8b^4} z^2 J_2(z) + C_2$$

consequently,

$$M = C_1 z J_1(z) + C_2 z Y_1(z) + \frac{\pi w}{8b^4} Z^3 \times [J_2(z) Y_1(z) - Y_2(z) J_1(z)]$$

or

$$M = A x^{\frac{1}{2}} J_1(2bx^{\frac{1}{2}}) + Bx^{\frac{1}{2}} Y_1(2bx^{\frac{1}{2}}) + \frac{wx}{b_2}$$

Upon examination of the general solution, it will be noted that when n is greater than 2, the numerical values of z and $2-n$ are negative; and the solution thus contains negative non-integral powers of negative numbers $z^{\frac{2}{2-n}}$, $z^{\frac{4}{2-n}}$, and $(2-n)^{\frac{2n}{2-n}}$ which are in general complex quantities. In order to obviate this difficulty, the negative of the previous change of variable may be made; that is,

$$z = \frac{2bx^{1-\frac{n}{2}}}{(n-2)}$$

If this substitution is carried through, the only difference in the final form of the solution is that the term $(2-n)^{\frac{2n}{2-n}}$ is changed to $(n-2)^{\frac{2n}{n-2}}$; consequently if the absolute values are used in these three places, no trouble from complex quantities will be experienced. With these modifications the general solution is as follows:

$$M = V(z) z^{\frac{1}{2-n}} J_{\frac{1}{2-n}}(z) + W(z) z^{\frac{1}{n-2}} J_{\frac{1}{n-2}}(z)$$

where

$$V(z) = wb^{\frac{4}{n-2}} \cdot \frac{\pi}{\sin\left(\frac{\pi}{2-n}\right)} \cdot \frac{(2-n)^{\frac{2n}{2-n}}}{2^{\frac{1}{2-n}}} \cdot \left(\frac{1}{2}z\right)^{\frac{2}{2-n}} \times \sum_{r=0}^{\infty} \frac{(-1)^r}{r!} \cdot \frac{\left(\frac{1}{2}z\right)^{2r}}{\left(\frac{1}{2-n}+r\right)\Gamma\left(\frac{1-n}{2-n}+r\right)} + C_1$$

$$W(z) = -wb^{\frac{4}{n-2}} \cdot \frac{\pi}{\sin\left(\frac{\pi}{2-n}\right)} \cdot \frac{(2-n)^{\frac{2n}{2-n}}}{2^{\frac{1}{2-n}}} \cdot \left(\frac{1}{2}z\right)^{\frac{4}{2-n}} + \sum_{r=0}^{\infty} \frac{(-1)^r}{r!} \cdot \frac{\left(\frac{1}{2}z\right)^{2r}}{\left(\frac{2}{2-n}+r\right)\Gamma\left(\frac{3-n}{2-n}+r\right)} + C_2$$

$$z = \frac{2bx^{1-\frac{n}{2}}}{(2-n)}$$

The only two remaining values of taper for which the general solution will not apply are $n = 0$ and 2. When n is 0, the solution is

$$M = A \sin(bx) + B \cos(bx) + w/b^2$$

and the origin of the coordinate system is placed at one end of the beam.

When n is 2, the solution is

$$M = \frac{wx^2}{2+b^2} + \sqrt{x}\left(Ax^{\sqrt{\frac{1}{4}-b^2}} + Bx^{\sqrt{\frac{1}{4}-b^2}}\right) \quad b^2 < \tfrac{1}{4}$$

$$M = \frac{wx^2}{2+b^2} + A\sqrt{x}\sin\left(\sqrt{b^2-\tfrac{1}{4}}\log_e x + B\right) \quad b^2 > \tfrac{1}{4}$$

$$M = \frac{4}{9}wx^2 + \sqrt{x}\left(A + B\log_e x\right) \quad b^2 = \tfrac{1}{4}$$

When the index is an integer plus a half, Bessel functions of the first type can be expressed in terms of circular functions. This means that when n is 4/3, 4, 8/5, 8/3, etc., the Bessel functions may be eliminated by the expressions

$$J_{m+\frac{1}{2}}(z) = \sqrt{2/\pi}\,(-1)^m Z_{m+\frac{1}{2}}\left(z\frac{d}{dz}\right)^m\left(\frac{\sin z}{z}\right)$$

$$J_{-m-\frac{1}{2}}(z) = \sqrt{2/\pi} \cdot Z^{m+\frac{1}{2}}\left(\frac{1}{z}\frac{d}{dz}\right)^m\left(\frac{\cos z}{z}\right)$$

and more simple solutions may be obtained. The solution for $n = 4$ is

$$M = \frac{1}{2}wx^2 + x\sin\left(\frac{b}{x}\right)\left[A - \frac{1}{2}wb\,Ci\left(\frac{b}{x}\right)\right] + x\cos\left(\frac{b}{x}\right)\left[B + \frac{1}{2}wb\,Si\left(\frac{b}{x}\right)\right]$$

where

$$Ci(u) = .577215 + \log_e u - \frac{u^2}{2.2!} + \frac{u^4}{4.4!} \cdots\cdots$$

$\cdots\cdots$ (Integral Cosine)

$$Si(u) = u - \frac{u^3}{3.3!} + \frac{u^5}{5.5!} \cdots \text{(Integral Sine)}$$

A precaution that must be observed in using these equations is that since the bending moments are obtained as the difference of large quantities, five place accuracy is necessary in all computations if the final moment is to be accurate to three places. It must also be remembered that while these equations determine the bending moment in the beam, uniformly loaded over a single span, the item which determines the design of the beam is the stress in the beam. The point of maximum stress will often be a considerable distance from the point of maximum moment.

The Pasadena Junior College Wind Tunnel

A. A. MERRILL, *Pasadena Junior College*

(Received May 25, 1936)

IN the Technical Laboratory of the Pasadena Junior College, California, a wind tunnel has been in use for over two years. The comparative results obtained from this tunnel are good, and the quantitative values obtained are satisfactory as a first approximation. The tunnel is an open throat open end tunnel, the return of air taking place in a large room. The tunnel test section is enclosed in an airtight chamber. The general dimensions of the tunnel are show in Fig. 1.

A 36 x 6 inch model can be conveniently tested in the tunnel. The maximum velocity available of 70 ft./sec. then gives a test Reynold's number of about 200,000. The tunnel velocity distribution is good and the variation of velocity with time is small.

The forces are measured by means of a two-component balance, consisting mainly of a pantograph gate. The gate stands crosswind and swings in the direction of the drag. The lift distorts the pantograph from its rectangular shape through the flexing joints. Figs. 2, 3 and 4 show the relation of the parts. The top member is an 18 gauge steel tube 3 inches in diameter. It is held (see right hand side of Fig. 2) by three pieces of thin steel which flex about horizontal axes (C in Figs. 2 and 4) parallel to the wind. The steel tube, with its mounting, resists the torque about the neutral axis of the tube caused by the model drag. The lower horizontal member completes the pantograph. Between these two horizontal members is a lever which supports the weight of the instrument and the model. The lever is supported by a brass ribbon (.004" gauge), hanging from the floor of the test chamber. This flexing ribbon makes it possible to balance the tare weight of the instrument and model without affecting the drag readings. The vertical member supporting the model is provided with racks and pans for holding the weights necessary to balance the lift forces.

In Fig. 3 is shown the drag measurement system and the device for angle of attack adjustments. The fitting for holding the model rotates about a horizontal crosswind axis and is tied by a steel ribbon to the gear turned by the worm. The frame standing at 45° (see left side of Fig. 3) acts like a bell crank and this is the only point where the friction is not molecular, there being a slight motion of the frame relative to the curved knife edge supports. This frame is counterbalanced (not shown) so that the weight

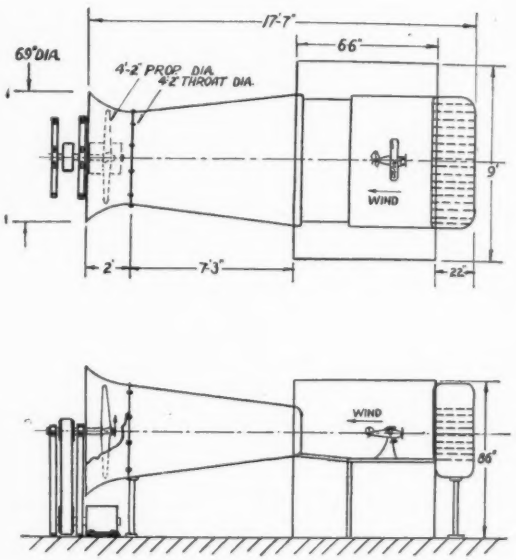

FIG. 1. Wind Tunnel at Pasadena Junior College.

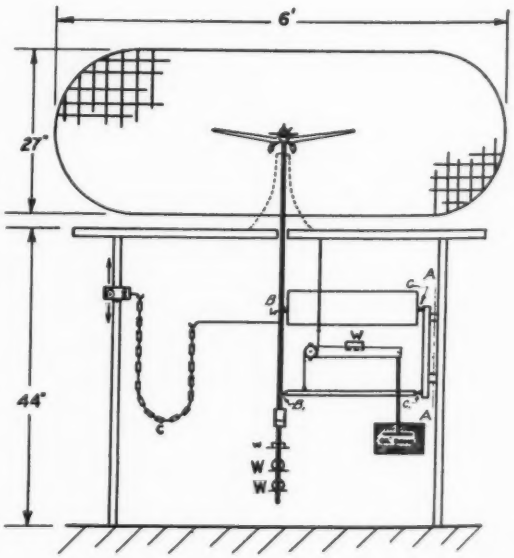

FIG. 2. Two component balance—front view.

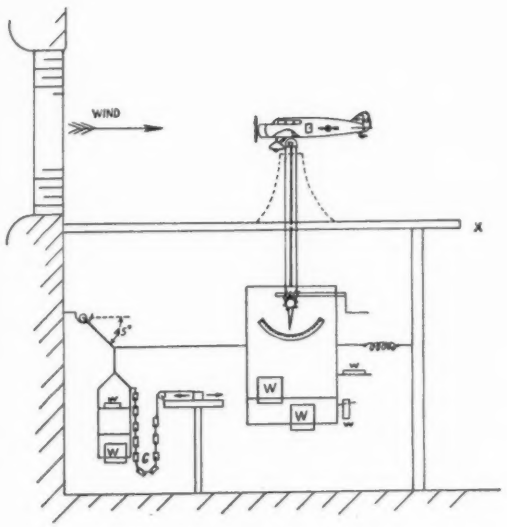

FIG. 3. Two component balance—side view.

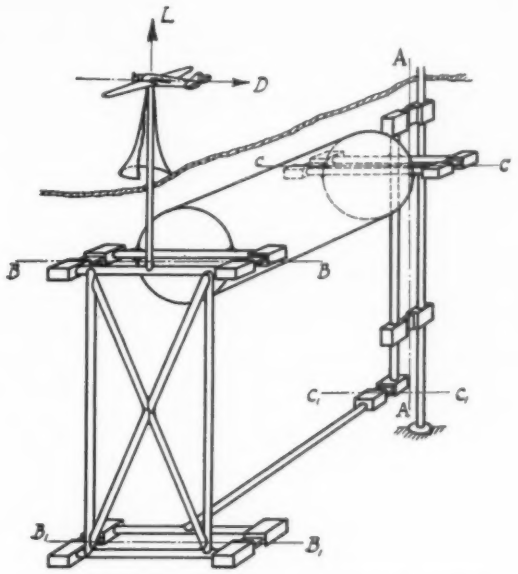

FIG. 4. Two component balance—perspective diagram.

of the frame and rack is only slightly unbalanced, and this small unbalanced moment is offset by a weak spring shown at the right which keeps the Drag system in tension without reducing the sensitivity.

Fig. 4 is a line perspective drawing showing the set-up of the pantograph gate. The whole instrument, with the model, swings about the A axes in the Drag direction. The up and down motion for Lift is about the C axes, all three being in the same vertical plane. The B axes complete the pantograph. In this drawing the frame, with the model, corresponds to the frame shown in Fig. 3 in which the worm and gear, and the racks for holding weights and Drag mechanism are shown. All the flexing connections are thin steel strips. There are of course many minor details which can not be shown here, but these particular details are not important. Any designer should be able to work out details to suit his preferences.

Measurements are made with three sets of weights, namely cans of metal washer blanks weighing 1, 2 and 5 pounds; and metal disks weighing 0.1, 0.2 and 0.5 pounds. Fine weighing down to 0.001 of a pound is done with chains as shown in Figs. 2 and 3. The operating ends of these chains are moved by hand and when released, remain fixed in position. In testing, the heavy weights are placed on the racks and pans and the observer maintains the zero position by adding or subtracting chain to the balance for both Lift and Drag. When satisfied with the condition, the observer pulls a cord which locks the manometer, thus giving the velocity head in the tunnel by means of a meniscus held fixed. Lift and Drag in pounds and the manometer reading are then recorded. Knowing the dimensions of the model, the velocity head and the two components in pounds, one slide rule setting for each angle and component gives the absolute coefficients. At present, the local tunnel corrections have not been determined. The work has been to perfect and reduce to the utmost simplicity the balance for measuring Lift and Drag. The technique has now been developed to the point where it is possible to test for Lift and Drag through 14 angular settings with the total elapsed time from placing the model in the tunnel to drawing the graphs for C_L an C_D being less than 90 minutes tor one man working alone. The whole equipment is inexpensive and easy to build and to operate. It is rugged and will not get out of order, nor will its sensitivity or accuracy be reduced by use.

In this wind tunnel there is a separate instrument for testing pitching moment and its correlation with tail settings, trim angle and c.g. position.

Some Secondary Factors Affecting Aircraft Performance

MANFRED RAUSCHER, *Massachusetts Institute of Technology*

(Received August 1, 1936)

AN engine burning fuel at a rate of w lb./sec. consumes air at a rate of about 15 w lb./sec. If the engine travels at a velocity of v ft./sec., it experiences an intake reaction of $15w\ v/g$ lb., equal to the rate of communication of momentum to the incoming air. Work is thus expended at a rate of $15w\ v^2/g$ ft.lb./sec. If u is the backward component of the exhaust velocity relative to the engine, the engine is subject to an exhaust reaction which does useful work at a rate of $16wv\ u/g$ ft.lb./sec. Gasoline has an energy content of about 15,000,000 ft.lb./lb., or simply ft. The engine efficiency may be assumed as 0.30, the propeller efficiency 0.80. The effective energy content of the fuel is thus $(0.30)(0.80)(15{,}000{,}000) = 3{,}600{,}000$ ft. approximately. Hence,

$$\frac{\text{Intake Power Loss}}{\text{Net Engine Power}} = \frac{15\,w\,v^2}{3{,}600{,}000\,wg} = \frac{v^2}{7{,}200{,}000}$$

and

$$\frac{\text{Exhaust Power Gain}}{\text{Net Engine Power}} = \frac{16\,w\,v\,u}{3{,}600{,}000\,wg} = \frac{v\,u}{7{,}700{,}000}.$$

Intake Power Loss

The intake power loss is inevitable with power plants consuming atmospheric air. While it is small at present day airspeeds (Fig. 1), it would seriously hinder the attainment of very high speeds, whether they were sought at low or at high altitudes.

Exhaust Power Gain

Exhaust power gains grow directly with the flying speed. They are already important at relatively low speeds (Fig. 2). At a speed of 300 m.p.h., for example, if the unmuffled exhaust speed is 1000 ft./sec., there is a difference of 6% between the total thrust furnished by an engine whose stacks point straight backwards and the thrust of an engine with stacks pointing straight sideways. Reducing u by muffling has the same effect as turning the exhaust stacks away from the line of flight; thus, at 300 m.p.h. a potential 6% thrust contribution from the exhaust is reduced to an actual contribution of 1.2% if the exhaust is muffled from 1000 ft./sec. to 200 ft./sec. and then allowed to escape straight backward. Any effects of muffling and stack orientation on the internal working of the engine are, of course, additional to the effects here considered.

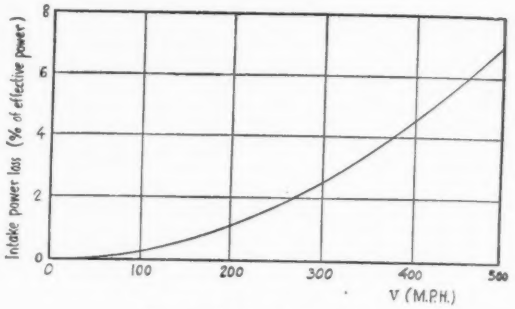

FIG. 1. Intake power loss.

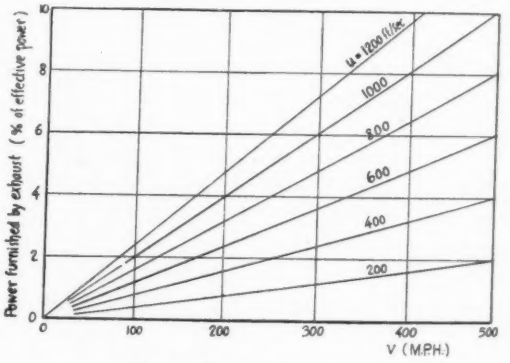

FIG. 2. Exhaust power gain.

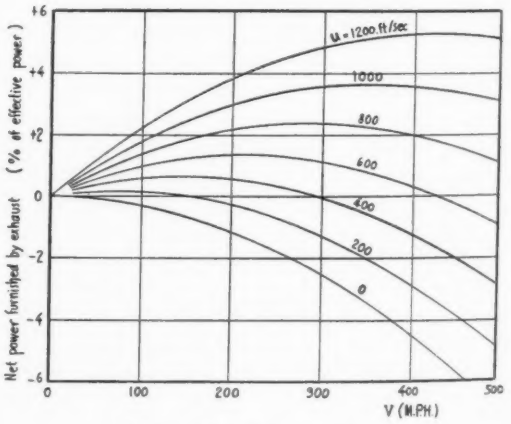

FIG. 3. Net exhaust power.

Net Exhaust Power

Fig. 3 is the result of combining Figs. 1 and 2. It shows the variation of the net exhaust power, or exhaust power gain minus intake power loss, with

flight speed. It suggests that around 200 m.p.h. the rocket action of the engine adds probably about 1% to the effective engine power in the average installation; and that, by suitable design of the exhaust system, anything between a net power gain of about 3% and a net loss of 1% is attainable from the intake and exhaust reactions. This range of power variation of about 4% at 200 m.p.h. is, of course, the same as that indicated by Fig. 2 for the exhaust power alone.

Altitude Effect

While the effects discussed so far depend on the flying altitude only indirectly—in the sense that v for a given airplane is a function of the air density, and u for a given engine installation varies with the back pressure of the atmosphere—, there is also a direct effect of the airplane's elevation on the effective energy content of the fuel. This altitude effect is an energy loss equal to the work required to raise the fuel from the ground to the altitude of steady operation. Thus, with a fuel having an effective energy content of 3,600,000 ft., as here assumed, there is a loss of 1% of the effective energy for every 36,000 feet of climb; which simply means that 1% of the fuel must be burned to raise the remaining fuel through 36,000 feet. If the total initial weight of the aircraft is n times the initial fuel load, the total loss of effective fuel energy becomes 1% for every $36{,}000/n$ feet of operating altitude above the starting level.

Book Reviews

The Old Flying Days, by Major C. C. Turner; Sampson Low, Marston & Co., Ltd., London, England, 1927; 374 pages, 6s.

Major C. C. Turner, who has been writing about aviation since 1907 and learned to fly in 1911, after his recent visit to the United States to make a tour of the United States airlines, sent a presentation copy of his book for the Institute library. Although written in 1927, it is a book that will never be out of date as it gives an eye-witness account of the beginning of British Aviation.

Jungens am Himmel, by Karl Theodor Haaren; Verlag Carl Reissner, Dresden, 1935; 142 pages, ill.; RM. 3.60.

The romance of gliding and soaring as enacted in the Rhoen mountains in Germany is unfolded in this interesting book. Young men come to the soaring meets from all parts of Germany, having made great sacrifices to secure funds for the trip. They built their machines in many cases at night with money which they would otherwise have spent for other pleasures.

The crew that tugs at the launching cords come with the hope that they may sometime and somehow have their chance in the air.

Probably in no form of sport is there such self-sacrifice and camaraderie exhibited as at soaring and gliding fields. Herr Haaren has written his book under such surroundings, and it gives the reader an excellent insight into the personal fascination of gliding.

Skyway to Asia, by William Stephen Grooch; Longmans, Green and Co., New York, 1936; 205 pages, $2.50.

When the saga of transoceanic air transport is written in the distant future this book will give historians much material that would otherwise have been overlooked had not the author kept careful notes.

The story of the expedition of the steamship New Haven, which was chartered by Pan American Airways to build commercial air bases across the Pacific—the stepping stones for the flying Clipper ships on their airway to the Orient—is written by an expert observer who was trained as a pilot by the Navy and had wide experience in piloting flying boats.

The building of bases for flying boats on the islands of Midway, Wake and Guam, required courage and ingenuity which are described with the pen of an expert by Mr. Grooch. To erect a station on a coral reef with docks, ramps, radio masts, offices, living quarters, kitchens equipped with electric lights, cold storage and power, required the transport of innumerable supplies and expert installation under peculiarly difficult conditions.

The book relates the trials and hardships of the mixed crew of seamen, carpenters, divers and aeronautical specialists, all of whom may be regarded as pioneers in this new field of aerial endeavor.

Of aeronautical organizations there apparently is no end. When the Ancient and Royal Order of the Gooneys is mentioned in aeronautical circles it must not be regarded as a chapter of the Quiet Birdmen, but an entirely new species which grew out of the camaraderie of those who found settlements for the harboring of transoceanic flying boats. The book describes the founding of the Order and gives its purposes. Mr. Grooch has written an aeronautical book of a new type and told his story interestingly.

Letters to the Editor

August 6, 1936.

To the Editor,
JOURNAL OF THE AERONAUTICAL SCIENCES,
Rockefeller Center,
New York, N. Y.

In reply to Mr. de Florez' letter of June 15.

The only 100 octane number (Army Method) fuels which have been in service use to date have involved the use of iso-octane as a blending agent. That a specific blending agent has been used to date hardly proves that this will always be necessary. That 100 and higher octane number fuels will always require the use of specific compounds as blending agents appears unlikely in view of the petroleum industries' activity in the development of polymer processes for the production of high octane number motor fuels from cracking still and other fixed gases available to the refiner. Some of these processes have shown that they can produce a mixture of compounds having octane numbers of approximately 100 without the addition of lead.

As long as high octane number fuels, whether single compounds such as iso-octane, di-isopropyl ether and toluol or a mixture of aromatic compounds are produced from the by-product gases resulting from cracking for the production of motor gasoline, it hardly appears that sacrifice of raw materials is involved except in the unlikely event of cracking being regarded as sacrifice of raw material.

Mr. deFlorez states that cracked fuels are not used for aircraft fuels on account of inability to pass the accelerated gum test. Cracked fuel has been used very successfully in considerable quantity both on the dynamometer and in flight without gum or other trouble. This fuel did pass the accelerated gum test and showed that it was stable as regards gum formation and loss of octane number for 12 month storage periods. That cracked aviation fuels are hardly used appears to be more due to the fact that it is difficult to obtain 87 octane number (Motor Method) with cracked products as at present produced, than to difficulties with gum. While it is true that cracked fuels, as at present produced, are mostly not suitable for long time storage it would seem that the petroleum industries' extensive knowledge of gum inhibitors should result in a rapid solution of this difficulty if cracked fuels should later prove desirable for technical or economic reasons.

Whatever the economics of the distribution of aircraft engine fuels, the situation as regards volume, storage, etc., it is not likely to be effected by octane number as long as aircraft fuels are special products and differ from motor fuels in other respects than octane number.

Mr. deFlorez refers to the possibility of excessive cylinder temperatures resulting from the use of high octane number fuels. Increase of octane number has been a factor of major importance in improvement of aircooled engine performance since it eliminated much of the trouble with high cylinder temperatures which was prevalent with fuels of 60 octane number or less. The published data[1, 2, 3] on 100 octane number fuels indicate that, in comparison with 87 octane number fuels, they make possible a considerable increase of output without increase of cylinder temperature. As regards the exercise of caution in the production of engines for the use of 100 octane fuel it may be pointed out that, in the light of present knowledge, no major change is involved. In fact, many existing engines designed for 87 octane number fuels can use 100 octane number to advantage since this allows greater take-off power and increased leaning off with the mixture control to reduce cruising consumption. Engine modification has so far been limited to increase of compression ratio to reduce the cruising specific fuel consumption. Should the supply of 100 octane number fuel prove inadequate or cost be too great, reduction of compression ratio by piston change does not represent a modification of great magnitude.

Mr. deFlorez does not refer to the advantage of increase of octane number in respect to reducing specific fuel consumption at cruising output to a level which is directly competitive with the compression ignition engine[3]. Reduction of cruising fuel consumption is of obvious advantage in aircraft where payload at long range is of major importance, and it can be shown that with a 2500-mile range 100 octane number fuel (Army Method) will earn a profit even though its cost is twice that of 87 octane number fuel (Motor Method). Just what price differential between fuels of 87 octane number (Motor Method) and those of higher octane number is economically justified will obviously depend on operating conditions, and too little experience is as yet available to enable a definite answer to be given as to the relation of value of octane number and operating conditions.

100 octane number fuel is now being used on a sufficiently large scale to make it possible to definitely determine whether it is worth its cost for both military and commercial use. It is the writer's opinion that fuels of 100 or higher octane number will be discarded if the added performance resulting from their use does not justify their increased cost, and they will come into general use as has the controllable pitch metal propeller, if cost is outweighed by performance gains.

S. D. HERON,
Ethyl Gasoline Corp.,
Research Laboratories,
Detroit.

August 12, 1936

To the Editor,
JOURNAL OF THE AERONAUTICAL SCIENCES
Rockefeller Center,
New York, N. Y.

Dear Sir:

The letter of June 15, 1936 by Mr. Luis de Florez, printed in the August Journal, is particularly interesting to the aircraft-engine industry as it brings up many points which have been under discussion for the past two or three years.

About three years ago the oil industry was contacted with reference to the possibilities of producing higher octane fuels for aircraft engines. I believe that almost without exception they stated that it would not be possible to produce gasolines with an octane number higher than 87 on a production basis. It was therefore interesting to note that according to Lieut. F. D. Klein's paper, printed in the August 1936 S.A.E. Journal, the Air Corps have purchased during the fiscal year beginning July 1, 1935 approximately 1,850,000 gallons of 100 octane fuel (Army

[1] F. D. Klein, *Aircraft Engine Performance with 100 octane fuel*, Journal of the Aeronautical Sciences, March 1935.

[2] F. D. Klein, *Future Possibilities of 100 Octane Aircraft Engine Fuel*, S.A.E. Journal, August, 1936.

[3] R. W. Young, *Air-Cooled Radial Aircraft Engine Performance Possibilities*, S.A.E. Journal, June 1936.

Method) and expect to buy about 3,500,000 gallons of the same type of fuel during the next fiscal year.

Exception can be taken to the first paragraph of Mr. de Florez' letter that limits are beginning to make themselves felt in the performance of aircraft engines thru the use of compression increase alone. As a matter of fact, one model with which the writer is familiar, had its performance increased 43% in the past four years without any increase in compression ratio or improvement in the fuel. The fuel appears to be the limiting factor at the present time as detonation occurs even under cruising conditions at low specific fuel consumptions. Therefore the greatest value of the higher octane fuels is the improvement in fuel consumption which can be obtained for long flights. Contrary to Mr. de Florez' statement, cylinder head temperatures are not as yet forming any limitations to increased outputs. The limit of cooling has not been reached by any means.

The oil industry to date have apparently been fortunate in having a product which was practically a raw material which requires very little processing but when faced with the problem of breaking the material down into its component parts and putting it together into a satisfactory composition which will be useful in aircraft engines, they are immediately very much alarmed. I recall the great concern which was experienced before the advent of cracked gasolines which have since their introduction increased the available supply of fuels for gasoline engines tremendously. This process is, of course, a step toward additional processing which must be done if more satisfactory aircraft-engine fuels are to be obtained.

Mr. A. L. Beall points out the following:

"In the beginning of the discussion of his subject, Mr. de Florez describes the preparation of 73 octane gasoline as "at the sacrifice of raw material and at the expense of additional processing." This does not seem to fit the facts which are, that 73 octane gasoline has been procured by segregating the crudes capable of producing 73 octane gasoline from straight distillation. The straight distillation is a preliminary operation with practically all crudes, and the only additional expense involved is that of segregating the crude for which no additional processes are required, but rather less processing, and for which the refiner receives a return of more than double what he would secure if the gasoline were marketed for automobile service. The increased price received for the gasoline probably pays a handsome profit on the crude segregation.

"A comparison of aviation gasoline with motor gasoline is entirely unwarranted. If a comparison is desired, it should be made with some other of the specialty products of the oil industry, such as cleaning solvents, mineral turpentine, and electric ignition tractor fuels, which, while they represent comparatively small volumes, are an important adjunct to the oil refiners' complete marketing of the products of a barrel of crude oil. No complaint about the processing of these products is heard, and the yield from most of them is on a comparative basis with that from aviation gasoline.

"The complaint about the specialized character of aircraft-engine fuels might well have been applied, and if memory is correct, was applied to the cracking process a few years back and to the then necessity of preparing fuels of higher anti-knock value for automobile engines. The analogy may be carried further in that the cracking process has resulted in tremendous economies to the oil industry and increased yields of marketable products from the crude, which may be reflected or again found to be true of the new processes necessary for the production of gasolines of the order of 95 to 100 octane number.

"The comparison with automobile fuel practice neglects to mention the enormous investment in marketing facilities which puts a plurality of gasoline pumps in every service station, with a consequent enormous distribution cost. The average automobile gasoline tank probably adds five gallons at an average stop at the pump. The aeroplane gasoline tank probably averages 300 gallons at a filling. The number of tanks and tank wagons in service for equivalent gallonage is but a fraction of that required for the automobile trade.

"There is probably not much reason to doubt that the oil industry is rapidly developing into a chemical industry, and its production of iso-octane is but one manifestation of its ability to convert crude oil into manufactured products, resulting in a material reduction in the waste of the crude and in a better balance of refinery production. It seems to be the viewpoint of the forward looking oil refiners that the oil industry must develop along chemical lines and make use of valuable by-products as a means of producing revenue.

"If the entire requirements of the aeroplane engine in this country, probably about 750,000 barrels of gasoline per year, were brought to high knock value by the addition of technical iso-octane to 73 octane aviation gasoline, a larger volume of material now sold at nominal prices would be up-graded and earn a premium over regular gasoline prices. The total investment would not be large when amortized over a reasonable period of time."

Contrary to Mr. de Florez' statement, engine designers are viewing the problem of high octane gasoline very seriously, so seriously in fact that during the past few years practically the whole oil industry connected with the manufacture of aircraft-engine fuels are getting very much sold on the fact that 100 octane fuel is here and here to stay.

There have been opinions from a number of the manufacturers of gasoline to the effect that the price per gallon will be little more than the present 87 octane (CFR Motor Method). Lieut. Klein points out in his article in the August S.A.E. Journal that the cost of the higher octane fuel per hour will be somewhat less than the 87 octane fuel with considerable saving in weight of fuel for a long flight.

There was one statement made by Mr. de Florez with which I am in agreement, that the manufacture of gasoline has been like the lumber business which concerns itself with cutting timber and making planks. The aircraft-engine industry passed that stage many years ago and it seems only reasonable that fuel which is used by these engines should keep up with the development of the engine.

The entire discussion has been based primarily on manufacture of iso-octane and the use of iso-octane for raising the octane number of gasoline by blending. Is it not reasonable to believe that there may be other methods of producing high octane fuel which will not require the expensive equipment which is necessary for the manufacture of iso-octane? It seems dangerous to predict that something of this nature cannot be found as such predictions usually turn out to be wrong.

Most of the questions which Mr. de Florez has asked in the last paragraph of his letter should be answered by the oil industry.

Regarding question No. 8, this question cannot be answered as no-one today knows the limit of the Otto-cycle gasoline engine. Further, the development of aircraft compression ignition engines will also require development of a satisfactory high grade fuel oil which might require more processing equipment and more disturbance in the refinery operations than development of a high octane gasoline.

My opinion of Mr. de Florez' letter is that it is just about two years late in appearing for discussion as most of the subjects mentioned in his letter have been very thoroughly discussed during that period and high octane fuel is now being used in considerable quantity and without question it will be used in greater quantities in the future.

ARTHUR NUTT
Wright Aeronautical Corporation
Paterson, New Jersey

Institute Notes

Honors

On the occasion of the 117th commencement exercises of Norwich University, June, 1936, Dr. Joseph S. Ames, Honorary Fellow of the Institute, President-Emeritus of Johns Hopkins University, and Chairman of the National Advisory Committee for Aeronautics was honored with the degree of Doctor of Laws. Because Dr. Ames was confined by illness the Trustees voted to waive the traditional rule against granting honorary degrees *in absentia*. Accordingly, represented by Dr. Howard, of the Norwich faculty, who studied under Dr. Ames over forty years ago, the latter received the following citation and degree:

"To Joseph Sweetman Ames, Son of Vermont, scholar, and executive; Eminently faithful and successful guardian of the heritage of the Four Doctors; Whose acceptance of this tribute we treasure as further evidence that our admiration and esteem are returned in kind; the degree, Doctor of Laws."

The Honorable William P. MacCracken, Jr., Pilot Member of the Institute, was also honored on this occasion with the degree of Doctor of Laws. The citation and degree follow:

"To William Patterson MacCracken, Jr., Indomitable adherent of American tenets of human rights; Honored and respected practitioner in the field of man's self imposed regulation; Pioneer in the development of government guidance of our newest means of transportation; Whose personal and professional integrity and ability we honor in honoring ourselves by conferring the degree, Doctor of Laws."

Science Exhibition at Atlantic City

The Institute of the Aeronautical Sciences will hold a cooperative exhibit at the Annual Science Exhibition in the Atlantic City Auditorium, December 28, 1936 to January 1, 1937, as an affiliated society of the American Association for the Advancement of Science.

The American Association for the Advancement of Science is the largest, most inclusive and most democratic scientific organization in the United States, having more than 18,000 members. Associated or affiliated with it are over 150 other scientific societies with a total net membership of more than 500,000. Its fifteen sections represent all the principal subdivisions of pure and applied science. At its annual meetings it brings together representatives of all sciences and many associated or affiliated societies. The representation at Atlantic City will be about 5,000 members in attendance.

The Annual Science Exhibition to be held will be a leading feature of the meetings. To the scientists in various fields, apparatus, equipment and demonstration are more meaningful than formally presented papers. The leading American scientists have been generous with their time and money in building up the exhibition to its present distinction.

Corporate Members of the Institute may exhibit their products without charge. Other aeronautical companies may exhibit upon payment of the usual fees. Information regarding exhibits may be secured from the Secretary of the Institute.

Institute Members to Attend Berlin Meeting

The Lilienthal-Gesellschaft für Luftahrt (the Lilienthal Society for Aeronautical Research) has invited three members of the Institute to be its guests at its annual meeting to be held in Germany, October 12–15. Dr. Clark B. Millikan of the California Institute of Technology is to present a paper on aerodynamics. Arthur Nutt of the Wright Aeronautical Corporation will present a paper on aeronautical engine problems. Major Lester D. Gardner, representing the Institute of the Aeronautical Sciences, will also attend.

On the first day of the meeting, the delegates will meet socially at the Neuen Palais at Potsdam. The technical sessions open at the Kroll Opera House in Berlin on the morning of October 13. In the afternoon, the delegates will be taken to Berlin-Gatow to visit the War Air Academy, the Technical Air Academy, and the War Air School. In the evening, a stag party will be held at the new home of the German Aero Club, the Haus der Flieger, in Berlin.

On the third day, the party will be taken to Göttingen to visit the Aerodynamic Experimental Station and especially to see the new high-pressure wind-tunnel. On the last day, a trip will be made to Dessau to see the Junkers Airplane Works.

By invitation of the German Air Ministry, Major Gardner will fly from Lakehurst to Germany on the Airship "Hindenburg", after which, through the courtesy of the Deutsche Luft Hansa and the Imperial Airways, he will fly to Rome, Paris, and London to visit members of the Institute.

The Lilienthal Society, which was organized last year, is the successor to the older aeronautical scientific and engineering societies and will coordinate the work of aeronautical research in Germany. Through meetings and publications it will disseminate technical knowledge of aeronautics.

The Society is governed by a Präsidium or Executive Committee, consisting of three Presidents. One of the Presidents is responsible for the management of the Society. Ministerialrat Adolf Baeumker occupies this office. The other Presidents are Prof.-Dr. Ludwig Prandtl of Göttingen, who is an Honorary Fellow of the Institute, and Prof. Dr. Carl Bosch of Heidelberg. The Senate is composed of twenty-five leaders in German aerodynamics who are chairmen of the technical committees and act as an advisory board to the Präsidium. The General Secretary is Prof. Dr. Karl Stuchtey, who acts under the direction of the Präsidium.

The membership is divided into three groups: regular members, corresponding members, and honorary members. Medals and prizes are offered to promote initiative in aeronautical research. In October of each year, the Society holds a meeting of members at which guests from abroad present papers.

Journals—$57 per Copy

Although the Institute has previously heard from many sources that the Journal is highly regarded among its readers in Europe, it is but lately that evidence has been received by which this valuation can now be placed at $57.00 per copy. A copy of the April 1936 issue was sent to a firm in England with a bill which read: 1 copy @ $.60 less 5% = $ 57. True.

with such an important decimal point omitted, this might be considered a much higher figure than is warranted for a non-profit organization to ask for its Journal, but the recipient sent by return mail a money order for £11/6/6 to cover the amount. It was returned and will undoubtedly be received with appreciation by the sender.

Necrology

LOUIS BLÉRIOT

In October, 1934, when he visited the United States as a delegate to the F.A.I. conference in Washington, Louis Blériot and Mme. Blériot visited the offices of the Institute and he expressed his appreciation of his recent election as a MEMBER.

On August 2 he died of heart failure at his home in Paris. He was 64 years old. By his death the Institute loses one of its most distinguished MEMBERS and the aeronautical world a great pioneer. The following cable was sent to Mme. Blériot from the Institute:

"Accept sincerest sympathy for loss of our distinguished MEMBER and great aeronautical pioneer. Regretted by entire membership.

Institute of the Aeronautical Sciences".

Early on the morning of July 25, 1909, at Northfall Meadows, about two miles east of Dover, Louis Blériot had just accomplished the seemingly impossible—crossing the English Channel in a heavier-than-air flying machine.

The pilot, then 37, was limping about on one foot. The Channel crossing, which was made well within half an hour, and, as the newspapers of the day said, "twice as swiftly as the fastest mail boat", marked an epoch in aviation history.

Many years later, when Colonel Lindbergh made his solo flight across the Atlantic, he exclaimed:

"I shall always regard you as my master."

"Ah, but you, my son," replied M. Blériot, "you are the prophet of a new era when flying will be as common as motor and steamship traffic is today."

When Louis Blériot flew the Channel hardly any one took flying seriously. Six days before he succeeded, another Frenchman, Hubert Latham, fell into the Channel when attempting the first over-water flight. M. Latham was supposed to have made his second attempt the very morning that M. Blériot flew across, but he overslept.

M. Blériot was both inventor and pilot. In 1900 he constructed a plane with flapping wings, which everybody laughed at. The Wright Brothers later gave him valuable ideas, and he produced a machine that would fly, but not very far. In July, 1908, he remained in the air for 8 minutes and 30 seconds, and made new records of 36 minutes and 55 seconds and of 50 minutes and 8 seconds.

The Blériot's monoplane of 1909 was a crude affair compared to modern aircraft. It had a wing-spread of twenty-four feet and a 22hp. engine. The French torpedo boat destroyer Escopette was to escort the plane across the channel, but, to the astonishment of all concerned, M. Blériot, outdistanced the warship and flew across at an average altitude of 250 feet at an average speed of 45 m.p.h. His plane weighed 500 lbs., including the weight of the pilot, and he had enough gasoline for two hours. The plane was constructed of wood and canvas. Its three cylinder engine by Signor Anzani was one of the best engines available at that time. The wind velocity was 20 m.p.h. and the sea was choppy.

M. Blériot's feat was hailed the world over. He received The Daily Mail $5000 prize. A British journalist wrote at the time:

"M. Blériot is the most daring aviator in the world. He has met with more than fifty accidents while engaged in flying, but so far he has escaped serious injury. He has learned how to save himself when he falls, and when spectators rush up expecting to find that he has broken a leg or an arm he picks himself up and begins to give directions to his mechanics as to the necessary repairs. He seems to realize in an instant the extent of the damage and to know exactly what must be done to make the machine airworthy."

Not long afterward M. Blériot made fresh short-distance records. At an aviation meet, where such pioneers as Glenn Curtiss, Paulhan, Latham and Bunau-Varilla took part near Paris, he made three world's records in one afternoon.

In December, 1909, M. Blériot crashed on a housetop at Constantinople and broke three ribs. He than gave up flying and devoted himself to the manufacture of airplanes, mainly for commercial purposes. During the World War he also constructed fighting planes.

In 1912 M. Blériot made his first visit to the United States, and then predicted transatlantic flights.

M. Blériot held Pilot License No. 1. Glenn Curtiss had No. 2, Henry and Maurice Farman had Nos. 5 and 6, and Wilbur Wright had No. 15. In 1929 commemorative celebrations were held at Calais, Paris and London, and M. Blériot received the insignia of Commander of the Legion of Honor. In 1931 he offered a cup for the first airplane to attain a speed of 650 m.p.h.

Personnel Opportunities

The Personnel Bureau serves organizations seeking to employ aeronautical specialists as well as individual members. The Bureau has been the means of arranging several very successful connections for members.

Any member or organization may have requirements listed without charge.

Available

Design engineer wishes to make new connection. Fifteen years' military and commercial aircraft experience in England and America. Would prefer technical post where knowledge of skin-stressed metal structures and aerodynamics could be used to advantage. Thoroughly familiar with Army and D.C. requirements. Graduate aeronautical engineer, London University, 1922. Write Box 46, Institute of the Aeronautical Sciences.

Recently graduated Student Members of the Institute wishing to secure some connection in the industry have forwarded to the Institute complete biographies of themselves and records of their school work. It would be appreciated if members or organizations offering employment to this type of personnel would write Box 47, Institute of the Aeronautical Sciences, stating their requirements.

Wanted

Man to take care of aviation instruction on a public school adult basis in an Eastern State. Technical graduate and holder of Department of Commerce License in one of the non-flight branches of the industry preferred. Teaching experience is not ncessary, but applicant should have suitable personality for such work. Salary about $3500 per year. Write Box 48, Institute of the Aeronautical Sciences.

Exchanges

The Institute exchanges the Journal with many other aeronautical periodicals. They are kept on file at the Skyport in Rockefeller Center, New York City, where members may read them. As readers of the Journal may wish to subscribe to some of them, a list of these periodicals with their addresses is published here. Information regarding subscription prices may be secured from the Secretary of the Institute.

Aero, Maneesikatu 2, Helsingfors, Finland.

Aero Digest, 515 Madison Ave., New York City.

Aeronautica Argentina, Velez Sarsfield 57, Cordoba, Argentina.

L'Aeronautique, 55 Quai des Grands-Augustins, Paris, France.

L'Aerophile, 7 Rue Saint-Lazare, Paris, France.

The Aeroplane, 175 Piccadilly, London, W.1, England.

L'Aerotecnica, Via delle Coppelle 35, Rome, Italy.

Les Ailes, 77 Boulevard Malesherbes, Paris, France.

Aircraft Engineering, 2 Bloomsbury Place, London, E.C.1, England.

Air Law Review, Washington Square East, New York City.

Asas, Caixa Postal 1967, Rio de Janeiro, Brazil.

Astronautics, American Rocket Society, 31 West 86th Street, New York, N. Y.

Aviation, 330 West 42nd St., New York City.

Aviation Weekly, 9401 Western Ave., Los Angeles, California.

L'Aviazione, Corso Umberto 504, Rome, Italy.

Boletin de Aeronautica Civil, Calle Azcuenaga 923, Buenos Aires, Argentina.

Boletin Oficial de la Direccion General de Aeronautica, Magdalena 12, Madrid, Spain.

Bulletin du Service Technique de l'Aeronautique, 72 chaussee de Waterloo, Rhode-Saint-Genese, Belgium.

Bulletin of the American Meteorological Society, Blue Hill Observatory, Milton, Massachusetts.

Bulletin Officiel du R.A.A., 6, Rue de Mezieres, Paris (6), France.

Bulletin Technique du Bureau Veritas, 31 rue Henri-Rochfort, Paris (17), France.

Canadian Aviation, Journal Building, Ottawa, Canada.

Deutsche Luftwacht, Schoeneberger Ufer 46, Berlin W35, Germany.

Les Fiches Aeronautiques, 6 rue Galilee, Paris, France.

Flight, Dorset House, Stamford St., London, S.E.1, England.

Flugwesen, Konviktska 22, Prague 1, Czechoslovakia.

Indian Aviation, P. O. Box 2361, Calcutta, India.

Journal of Air Law, Northwestern University, Chicago.

Journal of the Institute of Engineers, Australia, Science House, Gloucester and Essex Sts., Sydney, N. S. W., Australia.

Journal of the Royal Aeronautical Society, 7 Albemarle St., Piccadilly, London, W.1, England.

Journal of Scientific Instruments, 1 Lowther Gardens, Exhibition Rd., London, S.W.7, England.

Journal of the Society of Automotive Engineers, 29 West 39th St., New York City.

Letectvi, Celetna 13, Praha I, Czechoslovakia.

Luftfahrt-Forschung, Verlag Oldenbourg, Munich 1, Germany.

Die Luftreise, Lindenstr. 35, Berlin SW68, Germany.

Luftfahrt-Literaturschau, Z.W.B. bei der D.V.L., Berlin-Adlershof, Germany.

Model Airplane News, 551 Fifth Avenue, New York City.

Model Aviation, The American Academy for Model Aeronautics, 1733 RCA Building, Rockefeller Center, New York, N. Y.

Monthly Weather Review, U. S. Dept. of Agriculture, Washington, D. C.

Motor and Flying, 24 Bond St., Sydney, N. S. W., Australia.

National Aeronautic Magazine, Dupont Circle, Washington, D. C.

Official Aviation Guide, 608 S. Dearborn St., Chicago.

The Pilot, Grand Central Air Terminal, Glendale, California.

Il Politecnico, Via Spiga 32, Milan (2/7), Italy.

Popular Aviation, 608 S. Dearborn St., Chicago.

Proceedings of Institute of Radio Engineers, 330 W. 42d St., New York City.

Review of Scientific Instruments, 175 Fifth Ave., New York City.

Revista de Aeronautica, Ministerio de la Guerra, Apartado 1047, Madrid, Spain.

Revue de l'Armee de l'Air, 55 quai des Grands-Augustins, Paris, France.

Revue du Ministere de l'Air, 71 avenue des Champs-Elysees, Paris, (8), France.

Rivista Aeronautica, Ministero dell'Aeronautica, Rome, Italy.

The Royal Air Force Quarterly, Gale & Polden Ltd., 2 Amen Corner, London, E.C.4, England.

Southern Flight, Ledger Building, Fort Worth, Texas. Texas.

Sportsman Pilot, 515 Madison Ave., New York City.

Technika Vosdushnogo Flota, U1. Radio 16, Moscow 16, U. S. S. R.

La Technique Aeronautique, 2 rue Blanche, Paris (9), France.

U. S. Air Services, Transportation Building, Washington, D. C.

Western Flying, 420 S. San Pedro St., Los Angeles, California.

Wirtschaft Technik Verkehr, Alte Jakobstr. 148/155, Berlin SW68, Germany.

Zeitschrift für angewandte Mathematik und Mechanik, Kulmstr. 1, Dresden A24, Germany.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps. The articles listed may not be obtained from the Army Aeronautical Museum Library as these magazines are available to Wright Field personnel only.

Aerodynamics

The Aerodynamics Laboratory of the Swiss Federal Institute of Technology, Zurich. Air speeds up to 1500 m.p.h. may be obtained in the high-speed wind tunnel described which has a working space of 600 by 600 mm. when used as an open jet, or 400 by 400 mm. when entirely enclosed for high-speed work. It has been designed for research on high speeds such as are met with in air propellers, steam-turbine blades, and fans, as well as for research on external ballistics. It is possible to obtain high air speeds at low pressures and vice versa. The large tunnel has a jet opening of 9 ft. 9 in. by 6 ft. 11 in. and is adapted for air speeds up to 156 m.p.h. The return circuit is arranged vertically below the working space. Distribution of pressure and velocity throughout the large tunnel is diagrammatically illustrated, indicating that the high air speed is maintained only across the working section. A smaller wind tunnel with a 21.5-in. diameter orifice suitable for wind speeds of 20 to 40 meters per second, or 45 to 90 m.p.h., is also taken up. Long description. Engineering, June 26, 1936, pages 685–687, 698. 15 illus.

The Langley Field Conference. A. Klemin. The record of the year may be summed up as one of solid achievement without striking discoveries. A long summary of the discussions which took place during the recent N.A.C.A. Conference deals with airfoil research, aerodynamic interference, effect of slipstream on maximum lift, control after engine failure, evaluation of aileron characteristics, propellers for high-altitude flight, load effects of gusts, free-spinning wind tunnel, stable undercarriages, experiments in the tank, Diesel versus gasoline engines, engine cowling, and airships. Aircraft Engineering, July 1936, pages 197–199. 2 illus.

What is Top Speed? N.A.C.A. finding that air breaks away over the top of the wing at 575 m.p.h. is briefly discussed with reference to The Aeroplane's previous argument that for each air speed there is only one perfect streamline shape or airfoil section, and with the comment that a different section might have induced the air to behave properly in the tests. Aeroplane, June 24, 1936, page 735.

Charts, Crabs, and Charts. Bradley Jones. Humorous account of the "mass migration of intelligentsia to consult the Delphic Oracle at Langley Field." U. S. Air Services, June 1936, pages 23–24, 34.

Eleventh Annual Aircraft Engineering Conference. N.A.C.A. exhibitions in the propeller-research eight-foot high-speed, free-spinning, variable-density, atmospheric and full-scale wind tunnels, as well as in the tank, hangar, and the engine research laboratory at Langley Field. Subjects reviewed at the conferences on: flying and handling, aerodynamic efficiency and interference, aerodynamic and power-plant considerations of cowling and cooling, aircraft-engine research, seaplanes, and the autogiro are outlined. Journal Aeronautical Sciences, June 1936, pages 292–295. 1 illus.

Lift Slope and Distribution on Burnelli Aeroplanes. A. Klemin and B. Ruffner. Method developed to estimate the percentage of lift carried by the airfoil-section fuselage. Results of the calculation show that the airfoil body acts as a completely effective lifting surface in spite of its large thickness and in spite of the discontinuity produced. For stress calculation the N.A.C.A. has accepted a lift distribution of 25 per cent for a fuselage of this type. Derivation of the equation for the determination of lift distribution involving discontinuity is also given. Flight, Aircraft Engineer Supplement, June 18, 1936, pages 37–39. 3 illus.

Study of the Flow of Air Around a Model. M. H. Redon and M. F. Vinsonneau. Substitution of foam for smoke in the study of the flow of air around models in the wind tunnel. The equipment developed, ingredients and method of feeding the foam, system for displacement of the transmitter, and illumination are described in detail. Photographic possibilities are discussed and applications described for flow around a simple form and a wing profile, and studies of wing-fuselage joints and the marginal vortex. Results of an investigation to find an experimental process which would indicate the single trajectories issued from a single point in space. L'Aeronautique L'Aerotechnique Supplement, May 1936, pages 60–66. 16 illus.

Aircraft Design

Aerodynamic Similitude of Airplanes. L. Arsandaux. Principles of aerodynamic similitude of airplanes and their application to the study of airplanes and seaplanes of large size by means of flying models. Properties common to all airplanes aerodynamically similar are pointed out and a nomograph is illustrated for determining the correspondence of parameters relative to an airplane aerodynamically similar to a given airplane. As an example, the Short Scion Senior seaplane with four 90-hp. Pobjoy engines is described as a flying model for the Short Empire flying boat, although they are not geometrically similar, the Scion Senior having floats and the Empire a hull. Their characteristics and performance are compared. L'Aeronautique, L'Aerotechnique Supplement, May 1936, pages 53–60. 7 illus. 5 tables.

An Air Spoiler. A. A. Merrill. Air spoiler which decreases the C_L and increases the wing drag after ground contact, with some wind-tunnel results obtained. Journal Aeronautical Sciences, June 1936, page 291. 2 illus.

The Mauboussin "Hemiptere." Very large horizontal tail surfaces act as a second wing in the unusual design of low-wing monoplane described, the areas being 60 per cent of that of the main wing, and vertical tail surfaces are located at the extremities of the horizontal tail surfaces. Wind-tunnel results given indicate a decrease in drag at low angles and a gain in top speed, an increase in drag at large angles, favorable to landing, and an angular stagger increasing with lift. Characteristics, performance, and structural details. L'Aérophile, May 1936, pages 107–109. 7 illus.

Note on an Unconventional Airplane: The Motored Glider S.S.2. Capt. G. A. S. Stefanutti. Excellent performance of a new type of motored glider in take-off, flight and landing, and the advantages which could be obtained with an airplane of this design in regard to aerodynamic efficiency, efficiency of propeller and tail plane, improbability of flat spins, lifting capacity of the fuselage, elimination of tail vibration, and decrease in length of the airplane. In the motored glider longitudinal tail surfaces are mounted at the nose while the wing, located at the rear with the pusher engine, carries the two sets of vertical tail surfaces towards its tips. The front wheel is maneuverable. Construction and performance of the S.S. 2 are described in detail and the difficulties and defects of the canard airplane which are eliminated in the new design are discussed. Rivista Aeronautica, May 1936, pages 147–170. 26 illus.

A Note on Fuselages of Low Drag. J. R. Markham and S. Ober. A satisfactory pilot's cabin and windshield, together with the changes in shape of the back of the fuselage, increase the full-scale drag coefficient by only 10 per cent over that of an airship form, it was found in the described fuselage-drag studies to determine whether it was necessary for the fuselage drag of a large transport plan to exceed materially that of an airship form. An airship model was modified in the course of the tests to droop the nose and raise and deepen the tail, and then a cabin and windshield were added to provide sufficient outlook for the pilot. Wind-tunnel tests at M.I.T. in cooperation with United Aircraft Manufacturing Corporation. Journal Aeronautical Sciences, June 1936, pages 276–277. 5 illus.

Technological Developments of the Curtiss-Wright "Coupe." A. E. Lombard, Jr. Aerodynamic and structural research carried out in the development of the "Coupe" two-place all-metal cantilever monoplane. Wind-tunnel data on the effects of split flaps and on the drag of certain features of the airplane are reported. The structural tests described were made on a series of stiffened sheet-metal panels in edge compression and show good correlation with the "effective width" conception of the action of thin sheet in the buckled state. Fifteen types of stiffeners suitable for use on reinforced sheet structures subjected to compression are compared. The discussed results of flight tests and theoretical studies, combined with wind-tunnel tests of airfoils, indicate that the stalling characteristics of tapered monoplane wings can be appreciably improved without the use of aerodynamic twist, by using a highly cambered airfoil at the tip having a high value of C_L max. Journal Aeronautical Sciences, June 1936, pages 267–275. 17 illus. 10 equations.

Aeronautical Progress 1930–1936. E. F. Relf. Scale effect on lift near the stall; surface roughness effects on maximum lift; large drag increases produced by leakage of air through comparatively small openings and by design of cabin tops; the phenomena of interference; drag associated with engine cooling; comparison of the Fairey Fox of 1930 with the latest Hawker fighter and other types; advance in new aircraft materials; the operation of aircraft including the problems of landing and take-off, propellers, stability, control and flutter; and turbulence investigations. Concluded. Forest lecture before the Institution of Civil Engineers. Aircraft Engineering, July 1936, pages 185–190, 193. 19 illus.

An Analysis of the Influence of Drag on Speed of Modern Transport Planes. F. S. Chamberlin. Increases in the speed of present transports as high as 30 per cent, resulting in possible high speeds of between 260 and 280 m.p.h., are said to be obtainable by the use of more efficient lift increasing devices permitting increased wing loadings, further decrease in wing drag by increased taper, development of a horizontally-opposed type of engine, full retraction of landing gear and tail wheel, and improvement in fuselage streamline, including the use of a retractable windshield. The Boeing 247-D is used as an example in the calculations to show the drag distribution in a typical modern transport. Aero Digest, July 1936, pages 26–28, 4 illus. 3 tables.

Drag Analysis of Civil Aeroplanes. I. H. Crowe and W. E. Wood. A drag and efficiency analysis of 42 aircraft (nine of which are representative American types) is made not merely to compare British and U. S. aircraft, but also to give a general idea of the aerodynamic efficiency of the individual airplanes. The figures of merit for comparing aerodynamic efficiency and the five ways of specifying these figures are discussed and include: the simple overall lift/drag ratios; the total resistance of an airplane at top speed expressed as drag per unit weight at unit speed; the Everling quantities; Professor Melvill Jones' method of splitting up the drag into unavoidable drag and turbulence or eddy drag; and the turbulent drag at a given speed expressed as drag per 1000 lb. at 100 f.p.s. Aircraft Engineering, July 1936, pages 181–184. 3 tables.

An Experimental Towing Tank for Small Models. K. S. M. Davidson. The relationship between the resistances of small models of surface vessels as obtained in a towing tank, and the resistances of the corresponding full-size hulls. Tests of the bare model hulls are compared with tests of the same models roughened at the bow. Effects of the artificial stimulation of turbulence caused by roughening, in hastening transition from laminar to turbulent friction and in altering the point of separation of the boundary layer discussed. Stevens Institute of Technology tests. Journal Applied Mechanics, June 1936, pages A41–A46. 9 illus.

The Avery Brake. The Avery Brake described is incorporated in the hub in such a way that the wheel can be made completely detachable, the mechanism consisting of an annular inflatable capsule enclosed between two disks bolted together and to a fixed flange. Reference is made to a special coupling for hydraulic pipe lines. Aeroplane, June 17, 1936, pages 779–780. 3 illus.

Tail-Up. 3-Pointers! In the B.L.G. experimental undercarriage described a third wheel is placed directly in back of the standard two

wheels while these wheels are moved about a foot farther forward than in the standard airplane. The additional wheel is designed to prevent the increase of incidence causing ballooning of the airplane. Flight, June 18, 1936, pages 662–663. 4 illus.

A Retractable Planing Bottom. Retractable flying-boat planing bottom recently patented by Major Rennie and the Blackburn Company, and its advantages in reducing the height otherwise needed for adequate clearance of the propellers above the water and in overcoming the conflicting requirements of take-off and level flight. Aeroplane, June 10, 1936, page 744. 3 illus.

Skin Drag of High-Speed Aircraft. S. Hoerner. Errors in the original article and in the translation (which appeared in the April issue) are corrected. The corrections apply to a doubled value for k, calculation of airship drag, and methods of developing an efficiency figure to indicate the state of aerodynamic perfection of an aircraft. Aircraft Engineering, July 1936, page 200.

Stress Analysis and Structures

Design of Welded Trusses. A. Vogel. Methods used in the design of various parts of the welded Pratt truss are explained in detail with many diagrams. Welding Journal, June 1936, pages 12–18. 7 illus.

Impact on Beams. H. L. Mason. Transverse impact on beams the mass of which is of importance. Impacts which appear single to the eye are shown to consist in reality of several blows in quick succession. Historical development, Timoshenko's method of combining local deformation of the contact region with lateral vibration of the beam, and an experimental determination of flexural stresses in elastic and inelastic impact on a 3-in. I-beam by the use of a Westinghouse magnetic strain gage are discussed. Journal Applied Mechanics, June 1936, pages A55–A61. 18 illus.

Stability of Rectangular Plates Elastically Supported at the Edges. A. J. Miles. Exact solutions of stability problems of elastically supported rectangular plates involve the solution of a fourth-order partial-differential equasion in conjunction with certain boundary conditions and the resulting expressions from which the critical loads must be obtained are clumsy transcendental equations. The set of curves developed for the solution of these transcendental equations gives the critical load and also the number of half waves into which the plate buckles. Journal Applied Mechanics, June 1936, pages A47–A52. 7 illus.

Stress and Deflection of Rectangular Plates. I. A. Wojtaszak. Data on stresses and deflections of rectangular plates for several types of loading and edge conditions. Journal Applied Mechanics, June 1936, pages A71–A73. 15 illus.

Third Moments. R. C. Yates. A third moment is introduced as a distinct aid in calculating second moments (moments of inertia) for solids of revolution. The graphical determination is carried out in a manner similar to that for second moments. Supplementary remarks are made on the first, second, and third associated curves in the graphical analysis. Journal Applied Mechanics, June 1936, pages A53–A54. 7 illus.

Concentrated Loads on Wings. J. B. B. Owen. Effects of a number of concentrated loads on a two-spar wing structure are calculated in a discussion of an article by H. N. Horne entitled, "The Stressing of Monoplane Wings," which appeared in the March 26 and April 30 issues of the magazine. For the case of a concentrated antilift load of 3,000 lb. located at a point 25 in. forward of the front spar and 230 in. from the wing tip, the load system to produce bending deflections at all points in the spars and the torque distribution on the wing are calculated. Flight, Aircraft Engineer Supplement, June 18, 1936, pages 40–41. 3 illus.

The Stressing of Rigid-Jointed Frames. Capt. J. Morris. The simple method described was developed for expressing the equations of equilibrium (including end-load deflection effects) with an economy of variables, and for the solution of the equations by a novel system of iteration. Deformation of a single member of a plane frame, the braced frame with rigid joints, analysis of a three-bay braced plane frame and of a girder braced hexagonal ring, the plane frame with deformation normal to the plane of the frame, and the space frame are covered. Journal Royal Aeronautical Society, June 1936, pages 420–446. 9 illus. 4 tables.

Torsion in a Multi-Cell Section with Thin Walls. J. Lobley. Stress distribution in a multi-cell section, consisting of cells separated by thin walls, when subjected to torque, and a method of estimating the rigidity of such a section. Flight, Aircraft Engineer Supplement, June 18, 1936, pages 42–43. 2 illus.

Aircraft Maintenance

Aviation's Undercover Men. Lieut. Commander L. D. Webb. Importance of airplane maintenance as developed by the airlines with only a brief reference to the maintenance of military planes. General discussion. U. S. Air Services, July 1936, pages 17–19.

Aircraft

Here and There in Pictures. One of the new 176-m.p.h. Seversky basic trainers for the U. S. Army Air Corps, a new Spanish Fury, and a Vickers Vildebeest floatplane, as well as the Heinkel S5C and S5A floatplanes, Bristol Bulldogs, and Jaktfalts of the Swedish Air Force. Photographs only. Flight, June 4, 1936, pages 600b–600c. 6 illus.

CZECHOSLOVAKIA

The Benès-Mràz Beta-Minor. A. Frachet. Czechoslovakian Be-50 two-seater low-wing monoplane for training or touring with a top speed of 200–240 km. per hour and the Be-52, equipped as two seater or single seater for training in acrobatics with a top speed of 235 km. per hour. Description. Les Ailes, June 18, 1936, page 3. 3 illus.

FRANCE

The Loire 102 Transatlantic Seaplane. A. Frachet. The Loire 102 is equipped with four Hispano-Suiza 12 Xbrs 720-hp. engines, has a flying weight of 18,500 kg. and should attain a maximum speed of 310 km. per hour. Construction, characteristics, and theoretical performance. Les Ailes, June 11, 1936, pages 3 and 1. 3 illus.

S.F.A.N. New Light Airplanes. A. Frachet. Two new light airplanes, one a single-seater and the second a two-seater, as well as a seaplane, powered with 25-hp. and 35-hp. engines, respectively. Complete description of characteristics and performance. Les Ailes, June 4, 1936, page 3. 5 illus.

Single-Seat Trainer. Latest version of the Caudron C.690 military trainer for the French government. Photograph only. Aeroplane, June 17, 1936, page 766. 1 illus.

Technical Notes. The C.L.M. Diesel engine will be used to power the Bernard 82 record-breaking monoplane which has been ordered in the form of a reprisal bomber for the government. Brief reference. Les Ailes, June 4, 1936, page 4.

GERMANY

German Training Machines. Jungmann two-seater with a maximum speed of 105 m.p.h. and the Jungmeister single-seater with a maximum speed of 143 m.p.h. Very brief descriptions. Aeroplane, June 17, 1936, page 768. 3 illus.

Junkers New Twin. The Ju-86 ten-passenger plane briefly described may be fitted with Junkers Jumo, Pratt-Whitney Hornets, or Rolls-Royce Kestrel XVI engines and has a maximum speed of 226 m.p.h. It has smooth stressed-skin covering and the Junkers "double wing." Flight, June 18, 1936, page 657. 2 illus.

Longer description. Rivista Aeronautica, May 1936, pages 210–213. 2 illus.

GREAT BRITAIN

Another New Lightweight. Low-wing pusher monoplane designed by Capt. C. H. Latimer-Needham has a split-flap gear, trousered landing wheels, wing-root fillets, and a speed range of from 25 m.p.h. to 90 m.p.h. Brief description. Flight, June 18, 1936, page 653. 1 illus.

The First Symbol. Fairey Swordfish torpedo spotter and reconnaissance plane. Photograph only. Flight, June 4, 1936, page 605. 1 illus.

The Four Winds. The Handley-Page bomber-transport monoplane is having its Tigers replaced by a pair of Pegasus III's. Brief reference. Flight, June 11, 1936, page 622.

Monospar Modifications. Twin rudders, increased dihedral, and improved stability about all axes are the new features of the S.T. 25 referred to. Flight, June 4, 1936, page 607. 1 illus.

A New Fairey. Fairey light reconnaissance seaplane with a Napier Rapier 16-cylinder H engine is being produced for the British Air Ministry and is probably intended for operation from cruisers. Brief reference. Flight, June 4, 1936, page 596.

A.C.–136. Latest British army cooperation machine—a Westland—with Handley-Page slots and flaps. Photograph with brief details in caption. Flight, June 25, 1936, page 688. 1 illus.

Air and Water. Tests of the Mayo composite aircraft are planned for August. The upper component, a four-engined float seaplane will be ready for independent flight this month. The flying boat which will help it climb to its operational height will be ready three weeks later. Brief reference. Engineer, June 19, 1936, page 649.

What is claimed to be the world's fastest military airplane has been flown at Eastleigh. It is the Vickers Spitfire, an all metal low-wing monoplane with a Rolls Royce Merlin engine. Brief reference. Engineer, June 26, 1936, page 677.

All-Metal Planes at Royal Air Force Display. List of British military planes having all-metal construction, some using duralumin. Brief. Metal Industry, July 3, 1936, page 19.

Equipment and Re-Equipment. Present equipment of the Royal Air Force is the most efficient in the world." Drawings of the Gloster Gladiator and the Handley-Page Heyford heavy bomber (with retractable rotating turret) have a cut-away section to illustrate the location of equipment including the armament. R.A.F. aircraft, their duties and gear required are reviewed with a reference to the greater comfort for crews. Details of fighters, especially the Gladiator, equipment carried on a day-and-night fighter, and the Hawker Demon two-seater fighter are dealt with. Light, medium and heavy bombers are considered and the Army Co-operation, flying boats and trainers, as well as the Fleet Air Arm planes and their equipment described.

Photographs include: the Hawker F36/34, fighter, the Bristol Bulldog 11a and the Hawker Demon, Fury and the Gloster Gauntlet fighters; Hawker Hind light bomber; Westland Wallace and Fairey Gordon general purpose; Fairey Battle, Boulton and Paul Overstrand and Bristol 142 medium bombers; Bristol 130 bomber transport; Fairey Hendon heavy bomber; Vickers Vildebeest torpedo bomber; Avro Anson general reconnaissance; C.30 autogiros; Hawker Hector A.C. Saro London; Short Singapore III; Hawker Audax; Hawker Osprey fleet fighter; Blackburn Shark; Fairey Swordfish; Miles Nighthawk and Avro Tutor trainers.

The British are said to have the fastest experimental military aircraft, to have airplanes in large-scale quantity production which are faster than the fastest comparable experimental types abroad, and have aircraft actually in service which are at least as fast as anything in regular use by other powers. Flight, June 25, 1936, pages 668–680. 27 illus.

A Flying Boat for Open-Sea Reconnaissance. Two-page drawing of the Short Singapore III of the R.A.F. with a cut away section to illustrate the location of equipment and to indicate how it is possible for a man, if necessary, to pass from the bows all the way along the hull to the gun position at the extreme stern. Flight, June 25, 1936, pages 692–693. 1 illus.

The Four Winds. The new Rapier-engined Fairey reconnaissance seaplane is a biplane with flaps on upper and lower planes. Brief reference. Flight, June 25, 1936, page 681.

The Hatfield Show. British aircraft exhibited at the S.B.A.C.'s Types ranging from small civil two-seaters to large twin-engined bombers. Brief review. Flight, June 25, 1936, pages 708–710. 10 illus.

In the New Type Park. Vickers-Supermarine Spitfire fighter which does well over 300 m.p.h., Vickers Wellesley and Fairey Battle long-range light bombers, the 300-m.p.h. Hawker monoplane fighter, the Miles Nighthawk trainer, and the Bristol 142 "Rothmere," and Armstrong-Whitworth Whitley high-speed bombers. Photographs only. Aeroplane, June 24, 1936, pages 795–796. 12 illus.

New Aeroplanes at the S.B.A.C. Display. Nineteen British military and commercial airplanes shown at the exhibit of the Society of British Aircraft Constructors. Photographs only with brief descriptions in the captions. Aeroplane, June 24, 1936, pages 798–800. 19 illus.

The Newest Commercial Aeroplane. Double Eagle of the British Aircraft Manufacturing Company is a six-seater of high performance and novel appearance built entirely of wood. Drawing with cut away section to illustrate the wing construction and location of equipment as well as drawings of cabin and landing gear. Aeroplane, June 24, 1936, page 797. 4 illus.

A Pre-Display Demonstration. In connection with a general account of a demonstration of aircraft given to 200 distinguished guests by the Vickers, Supermarine, Bristol and Rolls Royce companies, photographs are included of a twin-engined unnamed Vickers bomber, the Wellesley Vickers bomber, the Vickers-Supermarine Spitfire I and the Vickers P.V. fighter which is powered with a Bristol Aquila sleeve-valve engine. Flight, June 25, 1936, pages 689, 690. 5 illus.

Show Piece. Vickers unnamed single-seat fighter and the Vickers unnamed long-range bomber of which the entire structure is a geodetic network covered with fabric. Photographs only. On the page following are two views of the Westland unnamed Army Cooperation high-wing braced monoplane with heated cabins for the crew. Aeroplane, June 24, 1936, pages 809–810. 5 illus.

HOLLAND

The Koolhoven FK 49 for Cartographic Surveys. The two-engined FK 49 high-wing monoplane, constructed especially for the execution of cartographic surveys for the Dutch Government, is said to be perfectly stable about the three axes and to be free from vibration. Description given. Rivista Aeronautica, May 1936, pages 213–215. 2 illus.

The Koolhoven FK 51 Military Biplane. The two-place training plane described may also be used for reconnaissance. Specifications when powered with an Armstrong-Siddeley Cheetah V 270-hp. engine and with a Cheetah IX 350-hp. engine. Rivista Aeronautica, May 1936, pages 215–217. 2 illus.

POLAND

Polish PZL-23 Airplane for Remote Reconnaissance, Bombardment and Combat. The Polish three-place plane carries an observer-bomber and a gunner besides the pilot, is powered with a Gnome-Rhône 14 KLrs 750-hp. engine, and has a top speed of 380 km. per hour at 4,000 m. Equipment, armament, field of fire, and bombs carried briefly described. L'Aérophile, May 1936, page 104. 2 illus.

U. S. A.

An American Trainer. Seversky plane adopted for advanced training in the U. S. Army Air Corps. Reference to the top and landing speeds, the special headrest, pontoons which can be fitted to the plane, and the sliding roof. Photograph only. Aeroplane, June 10, 1936, page 732. 1 illus.

De-Bufleting. Flaps, full of holes like colanders, are the latest American innovation and the newest Northrup two-place attack plane delivered to the Air Corps at Wright Field has flaps of this kind. Brief reference. Aeroplane, June 17, 1936, page 767.

North American Starts Production. Model B-T-9 basic training plane for the Army with details of the structure, flaps, landing gear, and other features. This is preceded by an article referring to an order for 95 planes for the Army and describing the factory. Western Flying, June 1936, pages 20–22. 2 illus.

United States. "The American military aviation" authorities have "ordered from Seversky thirty two-seaters for training in piloting high speed airplanes. The airplane is equipped with a 350/400-hp. engine." Photograph only. Les Ailes, June 4, 1936, page 6. 1 illus.

The New Ryan S-T for 1936. The S-T-A special model of the series is equipped with a super-charged Menasco C4S 150-hp. engine, and has a rate of climb of 1000 ft. per min. at more than 10,000 ft. and a cruising speed of 138 m.p.h. at 2000 ft. Improved flap control, tail-wheel swivel lock, and substitution of Alclad for aluminum are new features of the series discussed. Aero Digest, July 1936, pages 50, 52. 3 illus.

Aircraft Carriers

The Four Winds. Two aircraft carriers for the German Navy have been laid down and their construction well advanced. Displacing over 15,000 tons, the vessels will accommodate between fifty and sixty aircraft, including reconnaissance and bombing machines. Brief reference. Flight, June 25, 1936, page 61.

A New Aircraft Carrier. Japanese "Soryu" aircraft carrier of 10,500 tons for 40 airplanes. Very brief reference to some of the specifications compared to the "Ruijo." Revue de l'Armée de l'Air, June 1936, page 702.

Airships

The German Airship "Hindenburg." First airship to be designed for passenger transport as the Graf Zeppelin was originally intended for research and experiment. Construction, envelope materials and reinforcement, power plant, fuel storage, electrical requirements, control cabin, internal and external communication systems, ballast, passenger accommodations. Engineering, June 19, 1936, pages 657–658. 2 illus. and 7 illus. on suppl. plates.

Servicing A. S. Hindenburg at Lakehurst. Lieut. Commander C. V. S. Knox. Technical arrangements for mooring the Zeppelin, and methods of replenishing the hydrogen, compressed air, fuel and oil. U. S. Air Services, July 1936, pages 23–25.

Hail, Hindenburg. Lieut. R. Emerson. Scheduled flights of the LZ-129, as predicted and fulfilled, comparison of the airship with the S. S. Normandie and table of the Lakehurst servicing of the airship. General discussion. U. S. Air Services, June 1936, pages 13–16. 4 illus.

Balloons

Automotive Kite Balloons. A. F. de Moleyns. Development of the captive balloon in the last war briefly traced and features of the new Zodiac motor balloon powered by a 60-hp. radial engine described. The envelope has pleats at its sides and can expand against rubber cords which are laced. French balloon officers now have to qualify as airship pilots and go to Rochfort for experience on the Naval airships. The United States, Germany, and Italy are said to have been experimenting with motor balloons which can fly from point to point under their own power. Aeroplane, June 10, 1936, pages 745–746. 6 illus.

Propellers

Constant-Speed Propeller. F. W. Caldwell, E. Martin, T. B. Rhines. Operating requirements of propellers and the automatic constant-speed features of the Hamilton Standard propeller. Brief abstract of paper presented before the S.A.E. Automotive Industries, June 27, 1936, pages 907–908.

Profiles for Propellers. G. M. Gillen. New propeller profiling machine designed by Engineering and Research Corp. for cutting the profiles on metal blades for airplane propellers accurately to 0.002 in. Machine details with reference to the elimination of vibration in the bed. Welding Journal, June 1936, pages 9–10. 2 illus.

Propeller Design As Applied to Windmills. E. N. Fales. Fundamental principles governing the design of windmills to drive electric generators. The discussion covers the relation between propeller size and the wind speed, coefficients needed to predict the operating characteristics of a propeller-type windmill, a single-blade windmill which derives its pitch-changing moment from the torque of its counterbalance bar, distribution of winds in the United States, and results of a study of wind records at Dayton, Ohio, over a period of 7 years to find the relation between wind and windmill characteristics. Journal Aeronautical Sciences, June 1936, pages 278–281. 7 illus.

Propeller Vibration. K. Luerenbaum. Three different kinds of free vibration of crankshaft-propeller systems and two forms of propeller vibration are discussed by a member of the DVL staff. Fractures due to longitudinal or accordeon-type vibration of the crankshaft are taken up and DVL tests are described which were made to develop a reduction formula for longitudinal stiffness (corresponding to that for the torsional stiffness of crankthrows) to determine in advance the natural frequency of longitudinal vibration. A flexible connection is proposed between the crankshaft and propeller so that only the mean torque of the crankshaft would be transmitted to the propeller. Vibration characteristics of an engine with rigidly mounted and flexibly-driven propellers, respectively, are illustrated. Abstract of paper presented before the S.A.E. Automotive Industries, June 27, 1936, pages 914–915, 917. 3 illus.

Rocket Propulsion

The Design of a Stratosphere Rocket. A. Africano. Present development of the rocket motor is considered as sufficient to propel a meteorological rocket to an altitude of 7½ miles. American Rocket Society motor tests, comparative performance of gunpowder and alcohol as a rocket fuel, empirical rocket-design formulas developed from test data, rational design of a liquid-fuel rocket, calculation of the probable altitude, efficiency of flight, and the losses which occur are discussed. Journal Aeronautical Sciences, June 1936, pages 287–290. 5 illus. 7 equations.

Practical Rocketry. Experiments of Professor Goddard with rockets are briefly reviewed. Aeroplane, June 17, 1936, pages 766–767.

Records

Tables of Official Aviation Records. World and international records approved by the F.A.I. to May 1, 1936, including those for airplanes and seaplanes. L'Aéronautique, May 1936, 2 tables on supplementary sheets.

Engine Design and Research

Carburetion Practice in Aero Engines. F. C. Stokes. Carburetor development during 1929–1930. Stromberg delayed-action accelerating pump, Bristol Hobson arrangement of carburetor control linkage with boost control, Claudel-Hobson A.V.T. 80 carburetor on the Pagasus supercharged engine, Rolls-Royce carburetors in the supercharged Kestrel and the "R" engines, the Hobson-Penn automatic mixture control, the S. U. carburetor, and the Pratt and Whitney automatic mixture and power control unit are described as examples of development during this period. Concluded. Aircraft Engineering, July 1936, pages 194–196. 10 illus.

The Critical Speed of Crankshafts. J. L. Beilschmidt. Procedure for estimating whip in shafts of other than constant section incorporating rotating masses. Formulas are given for calculating the deflection due to individual loads acting at definite points and to the weight of the shaft. Aircraft Engineering, July 1936, pages 191–193. 11 illus.

Fundamental Observations on Two-Cycle Methods. H. J. Venediger. Development of two-cycle engines. Comparison of four- and two-cycle methods, the constant control diagram, independence of speed, variable control diagram, control of cross section in regard to time, output per liter characteristic at $\int f\,dt$ control, and status of the technique are discussed. Automobiltechnische Zeitschrift, June 10, 1936, pages 273–280. 25 illus.

Period of the Vibratory Process Accompanying Combustion in Explosion-Type Motor. A Labarth and R. Vichniewsky. Photographic recording of pressure-time diagrams taken by the photocathodic method. On parts of the diagrams corresponding to the combustion process the existence of a vibratory phenomenon having a frequency of the order of 2000 periods per second was discovered. The amplitude of these vibrations which are superimposed on the variations of pressure due to the combustion never exceeds under ordinary conditions 4 to 5 per cent of the maximum pressure. Very much greater amplitudes of vibration can be obtained, however, if the compression ratio is exceeded or highly detonating fuels are employed. Abstract from Comptes Rendus des Séances de l'Académie des Sciences February 24. Mechanical Engineering, June 1936, pages 378–379. 1 illus.

Aircraft Engine Lubrication. A. L. Beall. An oil groove serving as an oil reservoir in the bearing of a master connecting rod and a device designed for removing foreign matter and sludge from the oil entering the master rod bearing are described. Comparison with automobile-engine lubrication. Abstract of paper presented before the S.A.E. by research engineer, Wright Aero. Corp. Automotive Industries, June 27, 1936, pages 911–912. 2 illus.

Contribution to the Problem of Plain Bearings for High-Speed Internal-Combustion Engines. H. O. Heyer. Fundamental calculations in regard to the speed and surface pressure, the allowable pressure, and the selection of bearings on the basis of the effect of size and the structural formation are discussed in the first issue. The second deals with bearing materials and their applications, covering both soft and hard bearing metals. Automobiltechnische Zeitschrift, May 25, and June 10, 1936, pages 256–262 and 290–292. 4 illus.

Detonation and Oil Consumption. H. A. Everett and J. J. Mikita. Oil consumption of an engine increased materially when there was detonation, it was found in the tests described which were made at the Pennsylvania State College. Brief abstract of paper presented before the S.A.E. Automotive Industries, June 27, 1936, pages 917–918.

Distribution of Heat Loss to the Jackets in an Internal Combustion Engine Cylinder. C. F. Taylor. Fifty to fifty-five per cent of the heat lost was from the cylinder head, including the valve seats, 27 to 32 per cent from the cylinder barrel and 17 to 22 per cent from the exhaust port. Results of tests conducted at M.I.T. to determine the distribution of the heat flow between the various parts of the cylinder. Journal Aeronautical Sciences, June, 1936, pages 282–286. 6 illus. 2 tables.

Effect of Displacer-Piston. A. M. Rothrock. A visual study of air flow, fuel spray and flame formation in a displacer-piston compression-ignition engine. Five different forms of combustion chamber tested illustrated and conclusions reached from an analysis of the data discussed. Results of N.A.C.A. tests. Abstract of paper presented before the S.A.E. Automotive industries, June 27, 1936, pages 913–914. 1 illus.

The K-14 Certainly "Calamines" at Present but the NO-14 Does Not Overheat. The 1937 model of the K-14 Gnome-Rhone engine, named the NO-14, will develop 950 hp. at 4,000 meters and has a cooling surface of 18 to 25 sq. dm. per cylinder liter and a considerable increase in fin surface on the cylinder barrel. The NO-14 has been constructed and tested and reference is made to it in a discussion by M. P. L. Weiller regarding the problems of cooling radial engines. Brief reference is also made to results obtained with the Bloch and Amiot cowling in regard to "calamining" of the engine. Les Ailes, June 18, 1936, page 4.

Heat Rejection in Diesels. M. S. Huckle and H. V. Nutt. Rate of heat flow to the jacket water increased more rapidly with load in the Diesel than in a carburetor engine in the tests described and the rate of heat rejection to the jacket water was much greater in a turbulent than in a quiescent engine. Brief abstract of paper presented before the S.A.E. Automotive Industries, June 27, 1936, page 917.

Liquid-Cooled Air Engines. H. Wood. The military aircraft engine of the near future will be built in units of at least 1,600 hp. with from 9 to 30 cylinders, and the horsepower per sq. in. of piston area will be 3.86. Engine cooling systems and two methods being investigated by Rolls Royce for making cylinder heads without involving the use of castings are referred to. Rolls Royce tests of the harmful effects of detonation are discussed, especially in regard to the effect of cylinder size on detonation. Kestrel and Merlin Engines are briefly described. Abstract of paper presented before the S.A.E. Automotive Industries, June 27, 1936, pages 910–911. 2 illus.

Supercharged Ultra-Lightweights? A supercharged Austin Seven car engine adapted to ultra-light aircraft work is estimated to give 40 b. hp. at 3,500 r.p.m. Brief details of engine redesigned by P. Almack and G. S. Davidson. Flight, June 11, 1936, page 624.

Engine Manufacture

The Forging of Crankshafts for Aircraft Engines in U.S.S.R. M. Precoul. Various operations from fabrication of the ingot and its thermal treatment to stamping are described briefly and a method of control and micrographic analysis referred to. L'Aérophile, May, 1936, page 110.

Profilograph. Profilograph installed in the new Ford chemical and metallurgical laboratory for making greatly magnified records of surface irregularities on the Ford V-8 Piston pin. Photograph only. Automotive Industries, June 27, 1936, page 893. 1 illus.

Engine Testing

Measurement of Torsional Elasticity in Crankshafts. J. Geiger. Various methods for the experimental determination of the torsional elasticity of the cranked portion of the shaft. Automobiltechnische Zeitschrift, June 10, 1936, pages 283–284.

Photo-Electric Combustion Analysis. R. A. Rose, G. C. Wilson and R. R. Benedict. High-speed indicating system for studying combustion properties in Diesel and gasoline engines. Brief outline of three impulses simultaneously recorded for a single cycle, and explanation of why the combustion process is more complicated in the Diesel. Short abstract of paper presented before the S.A.E. Oil & Gas Journal, July, 1936, page 55.

Is It Necessary to Approve Engines in Flight? M. Victor. Tests of engines with superchargers at the maximum momentary power they can develop as the best criterion of their endurance and strength, and investigations of the critical speeds are recommended by C. Waseige. Some flight tests and improvements to render bench tests more efficient and complete are proposed. Les Ailes, June 4, 1936, pages 4–5.

Photo-Electric Records of Diesel Engine Combustion. R. A. Rose, G. G. Wilson and R. R. Benedict. High-speed indicating system which records three simultaneous impulses. The neon-tube optical indicator, sensitivity of the photo-cell in the ultra-violet, infra-red and visible light as compared to human vision, test apparatus in which the photo-cell looked into the combustion chamber through a quartz rod which served as a window, and a later set-up are described. Abstract of paper presented before the S.A.E. Automotive Industries, June 20, 1936, pages 877-878. 3 illus.

Windows for Combustion Observation. Materials suitable for the construction of windows for the observation of phenomena inside combustion chambers were studied by G. Calinguert, S. D. Heron and R. Stair. Brief review of results obtained. Abstract of paper presented before the S.A.E. Automotive Industries, June 20, 1936, page 878. 2 illus.

Slow Motion Pictures of Knocking and Non-Knocking Engine Explosions Recorded with a New High-Sneed Camera. L. Withrow and H. M. Rassweiler. Requirements of the special high-speed camera, with a reference to observations at the time of knock. Brief abstract of paper presented before the S.A.E. Oil & Gas Journal, July 9, 1936, page 55.

Engines

Engines at the S.B.A.C. Show. Armstrong-Siddeley, Bristol, Cirrus-Hermes, DeHavilland, Pobjoy, Napier, Rolls Royce and Wolseley engines exhibited are briefly reviewed. (On pages 668–680 of this issue the engines powering the planes in action at the R.A.F. Display are referred to in the descriptions of the planes.) Flight, June 25, 1936, pages 683–684. 8 illus.

List of stand holds and engines and equipment displayed. Aeroplane, June 24, 1936, pages 801–806. 23 illus.

Menasco Model C4S and B6S Engines. Four-cylinder in-line inverted Pirate C4S supercharged engine is rated at 150 hp. at 2,260 r.p.m. at 3,000 ft. and the six-cylinder Buccaneer B6S is rated at 200 hp. at 2,250 r.p.m. at 4,500 ft. Long description with drawings and altitude performance curves. Aero Digest, July, 1936, pages 46, 48, 50. 9 illus.

Bristol "Pegasus" Engine. New design of cylinder head and barrel with a substantial increase in cooling area, sodium-cooled and stellited exhaust valves and stellited valve seats, hardened cylinder barrels, rubber buffer mounting, alternative reduction gear ratios, and facilities for the standardization of a controllable-pitch propeller are recent modifications. Long description of the latest Mark X 890/920-hp. engine and its various parts including the exhaust collector ring. Automobile Engineer, June, 1936, pages 221–224. 13 illus.

Continental Oil Engines. The MWM, Mercedes-Benz, Maybach, Hanomag, Kaeble, Hansa-Lloyd, Michel, Berliet, C.L.M., Chenard and Walcker, Delahaye, Panhard, Rochet-Schneider, Unic, Renault, Atlas, and Fiat oil engines, used for automobiles, trucks and rail cars, for the most part, are described and illustrated. Automobile Engineer, June 1936, pages 235–241. 22 illus.

The Four Winds. Two engines with outputs well over, 1,000 hp. are being tested by the U.S. Army Air Corps, one a two-row Wright and the other an in-line model of X formation made by the Allison Engineering Company. Brief reference. Flight, June 18, 1936, page 647.

The New Alvis Motors. In the near future the British company hopes to have on test the most powerful aircraft engine yet manufactured and to produce engines to a total of 15,000 hp. per week. Brief reference. Aeroplane, June 17, 1936, page 781.

The Saurer Diesel Engine for Automobiles and the Series of High-Speed Types Developed from It. B. Bolli. Designs of four types of Saurer light high-speed Diesel Engines for automobiles. Automobiltechnische Zeitschrift, April 25, 1936, pages 198–203. 11 illus.

Super-Scarab. Reduced frontal area, a more generously proportioned crankshaft, and provision of a carburetor air-intake valve to control preheated air temperatures are the major improvements in the new Warner Series 50 Super-Scarab 145-hp. engine. Description of new features with general specifications. Aviation, June, 1936, pages 38–39. 1 illus.

The Two-Row Radial Engine. C. W. Deeds. Advantages of the Pratt and Whitney two-row radial engine over the single-row type, with reference to the patented automatic mixture control, cast-on rocker box, pressure baffles and other features of the engine. Future trends predicted. Western Flying, June, 1936, pages 18–19.

Something New in Pistons. The Worldwin pistons have a system of internal construction by which cooling ribs connect the crown, thrust and trail walls and gudgeon-pin bosses so that the surfaces not actually in contact with the cylinder walls assist in cooling the piston. Two other Worldwin types are described, one of split-skirt or constant-clearance variety and the other with a different type of fins. Flight, June 4, 1936, page 600a. 1 illus.

Accessories

Engine Synchronizer. Visual synchronization of engines is obtained by means of the device developed by Central Air Lines for its Model A Stinsons. Few details. Aviation, June, 1936, page 45. 1 illus.

A Flame Trap. The Amal device for definitely preventing the passage of flame due to backfire has been approved by the British Air Ministry and is fitted to several well-known aircraft engines. Brief description. Automobile Engineer, June, 1936, page 220. 1 illus.

High-Speed Diesel Control. C. R. Alden. Governing equipment of the Ex-Cell-O injection pump is described with curves of volumetric efficiency and fuel quantity versus speed. Abstract of paper presented before the S.A.E. Automotive Industries, June 27, 1936, pages 906–907. 2 illus.

The Modern Method. Kigass Petrol Mist injector and spray nipple for priming aircraft engines. Brief details. Aeroplane, May 20, 1936, page 649. 1 illus.

Simplicated Screening. K.L.G. integrally screened spark plug for airplane engines. The screen is made in the form of a tubular extension of the spark-plug gland nut insulated internally with mica. Brief. Aeroplane, June 10, 1936, page 752. 1 illus.

Swiss-Roll Silencing. The Servais exhaust silencer for automobiles, which is very briefly described, consists of a sandwich-roll arrangement inside the ordinary tubular steel casing. A strip of expanded metal and absorbent material are arranged inside with a hollow part at the center so that the exhaust gases have an absolutely uninterrupted passage through, the various vibrations being absorbed by the packing material. The inventors are said to intend its development for aircraft and also to have ideas regarding the silencing of propellers. Aeroplane, June 17, 1936, page 280. 1 illus.

Fuels and Lubricants

A New High Octane Blending Agent. H. E. Buc and E. E. Aldrin. Isopropyl ether blend is a new fuel of high antiknock value apparently suitable in all respects for the modern high-output aircraft engine and potentially available in large quantities. The 100 O.N. is a propyl ether blend has a minimum specific fuel consumption which is 13 per cent lower than that for the 92 O.N. regular gasoline. The 100 O.N. blends of isopropyl ether and iso-octane are equal in power output and consumption under high power conditions. Test results given compare isopropyl ether with 100 Army octane fuel. Paper presented before the S.A.E. Oil & Gas Journal, June 18, 1936, pages 41–43. 5 illus. 4 tables.

Brief abstract. Automotive Industries, June 27, 1936, pages 912–913. 1 table.

Future Possibilities of 100 Octane Aircraft Engine Fuel. Lieut. F. D. Klein. To take maximum advantage of the 100-Octane fuel, engines must be specifically designed for its use. Fuels of highly aromatic content, containing no iso-octane, might be of decided value in the future. Reference to results of Air Corps tests on Army 92-octane, iso-octane, and iso-octane plus lead. Brief abstract of paper presented before the S.A.E. Oil & Gas Journal, July 9, 1936, page 55.

The Quality of Aviation Fuels and Quantity of Lead Permitted. U. S. Army Specifications 2–95, 2–93, and M–222 showing octane number, ethyl lead content, distillation, and other requirements, given in answer to an inquiry. Very brief. Oil & Gas Journal, July 9 1936, page 57.

Instruments

Gyroscopes or Wind Vanes? L. Constantin. Gyroscopes are compared with the author's invention for automatic piloting by means of wind vanes and reasons are given for the advantages of the latter device. Exclusive rights for developing and producing this device for all the French military and civil airplanes have been assigned to the author. The gyroscope is said to expose the airplane to danger when the engine speed varies accidentally. Advantages of the wind vanes on bombers in cloudy weather and stability obtainable with these vanes are referred to. Les Ailes, June 11, 1936, page 4.

Maintaining the Tachometer. C. L. Turner. Explanation of the Pioneer centrifugal and electric tachometers and maintenance methods. Western Flying, June, 1926, pages 16–18.

Navigation Instruments. The Smith TDF Av. 917 drift indicator, the Gatty cinemodrift indicator, the Aéra M10 and M100 and the Salmoiraghi "Stelvio" altimeters, and the Salmoiraghi altimetric compensator are described. L'Aérophile, May, 1936 111—112. 5 illus.

Robert Altimeter with Interference. An altimeter with electric transmission and its defects, essential characteristics of piezo-electric crystals, an altimeter with optical transmission, and the Robert R 13 altimeter which employs the optical system are described. Revue de l'Armee de l'Air, June, 1936, pages 710–716. 5 illus.

TESTING APPARATUS

Drop Test Jig. Boeing jig to determine load factors of the landing gear being installed on the Model 299 bombers for the Air Corps. A few details of the jig with a reference to tests and load the gear will withstand. Aero Digest, July, 1936, page 102. 1 illus.
Photograph only. U. S. Air Services, July, 1936, page 34. 1 illus.

Morane-Saulnier Device for Recording the Forces on the Controls. Equipment for recording the forces exerted on the stick and rudder bar. Details, principles of operation, liquid used, calibration, and results obtained with the device. Revue de l'Armée de l'Air, June, 1936, pages 674–686. 13 illus.

Some Measuring Equipment of the DVL. R. Sancery. Deflection recorders which may be mounted on the tail surfaces of airplanes as well as on the ailerons, recorders of the forces exerted on the stick, a pair of recorders of the forces exerted on the rudder, and recorders of the forces acting at the opening of parachutes are described in detail in regard to size and weights, method of mounting, and some results obtained. This article is followed by a brief one describing the Morane-Saulnier device for recording the forces on the stick. L'Aeronautique, May, 1936, pages 97–102. 18 illus.

Vibration Measurements in Airplanes. H. W. Koch. The Wass vibration indicator for measuring the vibration of an airplane as a whole is a leaf-spring seismograph with two masses each consisting of two parts. The normal natural frequencies of the device for measuring 6.5 cycles per second, can be reduced to two cycles per second, while the device can be regulated for any desired damping although one between 8:1 and 10:1 is generally used. Zeitschrift fuer Instrumentenkunde, June, 1936, pages 250–252. 3 illus.

Airport Equipment

Sonic Marker Beacon for Fog Aviation. C. W. Rice. Apparatus built for tests by the Army at Wright Field is described, a plan view and elevation of an imaginary airport in which sonic marker beacons are used as boundary markers are illustrated, and an imaginary blind landing made by the combined use of the sonic boundary marker and sonic altimeter equipment is explained. This is followed by an article entitled "The Sonic Locator, An Aid to Fog Navigation" by the same author. Journal Acoustical Society of America, July, 1936, pages 26–29 and 30–33. 5 illus. and 3 illus.

Radio

Landing Aircraft by Sound. Demonstration of the Lorenz blind landing system in England. Short general account with illustrations of airport antennas, airplane di-pole aerial, and remote control of receiver in the cockpit. Wireless World, June 26, 1936, page 627. 3 illus.

Air Traffic Control. British radio traffic-control and guiding system for airplanes outlined in a general discussion with illustrations of the Marconi equipment for the Empire flying boats and the medium-wave airport outfit of Radio Transmission Equipment, Ltd. Flight, May 21, 1936, pages 540b–540d. 6 illus.

Broadcast Beacons. J. P. Gaty. Faults to be found in the radio compass for air navigation and the solution of eight typical navigational problems involving its use. Diagrams illustrate: the determination of track and drift by the radio compass and gyro; locating an airport by means of one off-course radio station under conditions of bad visibility; maintaining track with the radio compass and gyro; direct determination of drift by the radio compass and gyro; descending though total overcast in a spiral around a radio station; explanation of radio-compass action in a spiral around a radio station; and blind approach to an airport with low ceiling and visibility (not zero). A table shows the location of 54 of the major broadcasting stations with respect to the nearest airport. Concluded. Aviation, June, 1936, pages 15–18. 8 illus.

Down the Beam. H. A. Taylor. Tests of Heston's blind approach system made by an amateur. Diagramatical section through the main beam shows how airplanes entering at different heights will reach the airport boundary at the same height. Flight, June 18, 1936, pages 648–649. 3 illus.

The Lightning Danger. Necessary precautions to be taken with a trailing aerial in the vicinity of large clouds from which rain, hail, or snow are falling. Very brief outline of "Notice to Airmen, No. 62." Flight, June 4, 1936, page 609.

The Radiaura. Hill's Radiaura equipment for indicating to one airplane the approach of others. A novel system of double modulation makes possible multiplex conversation between any number of transmitters within a predetermined range, it is claimed, and visual warning is given of the entrance of one, or any number, of airplanes within a danger zone of predetermined extent and depth around any given airplane. The British Air Ministry has ordered an experimental set. Brief description. Aeroplane, June 10, 1936, page 343. 1 illus.

Meteorology

Tiny Transparent Balloons Probe Stratosphere Secrets. Robot radio balloons of cellophane sent aloft to send back automatically information on hte stratosphere. Short general account of low cost compared with that of the Explorer I and II and results desired. Science News Letter, July 4, 1936, pages 12–13.

Modern Methods of Weather Forecasting for Aviation. Lieut. Colonel A. Verdurand. Origin and causes of meteorological phenomena, internal construction of the cyclone, determination of meteorological conditions at high altitudes, course of cyclones, relations of wind velocity and barometric gradient, general outline of air currents over the Atlantic and Europe between the Equator and Pole, disturbances due to the continents, and local disturbances due to high mountains. The appendices deal with principal types of clouds in cloudy systems and the cooperation of public transportation systems for the collection of meteorological observations. Forty-seven page discussion. Revue de l'Armée de l'Air, June, 1936, pages 613–660. 45 illus.

Materials

METALS

Chrome Molybdenum Steel for Aircraft. A. J. Herzig. Physical properties for sheet or strip, dimensions of test specimens used for thickness of sheet tested, recommended welding practice and welding rod, and effect of heat treatment on the physical properties of the welded tubing. Aero Digest, July, 1936, pages 32–33, 36. 4 illus. 2 tables.

Nickel Steels and Alloys in Aircraft Engines. Case-hardening low-carbon and oil- and water-hardening nickel steels used in aircraft engines. Characteristics of the individual steels in both classes and applications of each of the more important nickel, nickel-chromium or nickel-chromium-molyodenum steels in engine construction. Monel metal and iconel applications are also briefly referred to. Aero Digest, July, 1936, pages 38–39, 110. 2 illus. 1 table.

B. S. Aircraft Specifications. Mild steel sheets and strips (suitable for welding), 5 per cent nickel-steel sheets (not suitable for welding), low-carbon-steel sheets and strips, non-corrodible steel sheets, nickel-chromium steel sheets and strips, 6 F.1 4-ox. linen fabric and tape. Brief reference only to revisions of British Standard Aircraft Specifications. Aircraft Engineering, July, 1936, page 205.

Die Castings. H. Chase. Alloys for aircraft die castings and their applications. Composition and average physical properties of aluminum, magnesium, copper, and zinc die-casting alloys. Aero Digest, July 1936, pages 54, 56, 58. 5 illus. 1 table.

PAINT

Aircraft Finishing. G. H. Robertson. Nature, cause and remedy for common airplane finishing troubles and the pigmented-dope military system, the pigmented-dope commercial system, and the semi-pigmented dope system of aircraft finishing. Precautions in temperature and humidity control, applying reinforcing patches and finishing tape, sanding, spraying, recovering and refinishing, matching repairs in fabric rupture with the surrounding area, painting duralumin parts, and sanding and cleaning steel surfaces. Aero Digest, July 1936, pages 42, 45, 110, 112. 6 illus.

PLASTICS

Increasing Applications of Plastics. H. Pennington. Phenol-formaldehyde, urea-formaldehyde, nitrocellulose and cellulose acetate types of plastics, forms available, and the properties which make them particularly suitable materials for aircraft parts such as windows, windowscreens and cockpit enclosures, aerial cameras, instrument cases and instrument parts. Aero Digest, July 1936, pages 30-31, 112. 6 illus.

RUBBER

Thickol—A New Material Finds Varied Aircraft Uses. New synthetic rubber specified by U.S. Army Air Corps as material for fuel- and oil-line hose at Government airports. Resistance to oil, gasoline, and chemicals, and to oxidizing effects of air and ozone makes it an ideal material for airplane fuel- and oil-line hose, balloon covering, and linings for crash-resistant tanks, for repairing leaky fuel tanks, and for sealing cabins of planes to make air conditioning at altitude flying effective. Properties and applications especially its use in crash-resistant tanks. Aero Digest, July 1936, pages 29 and 110. 2 illus.

Versatile Synthetic Rubber. Thiokol as standard material in all gasoline and oil hose used by the United States Army Air Corps. It has been also found to be 25 times more effective than rubber in holding helium in the bags of balloons and dirigibles according to tests recently made. Brief. Scientific American, July 1936, pages 51–52.

Miscellaneous Equipment

At the S.B.A.C. "Static" Show. British aircraft equipment exhibits shown by nearly a hundred firms at Hatfield. Review of engine components and electrical equipment, propellers, undercarriages and brakes, instruments and controls, radio, airport equipment and lighting, fuels and lubricants, dopes, paints and preparations, metals and castings, engine parts, tubular work, parachutes, miscellaneous components and accessories, works equipment, and slot demonstrations. Flight, June 25, 1936, pages 694–703. 16 illus.

Equipment and Methods. Gasket compound, refrigerator for dural rivets, sound level indicator, Hypressure Jenny Model G vapor spray cleaning equipment, carbide tool grinders, reference charts for nickel steel, Gunk hydro-degreasing fluid, utility floodlights, portable hangar, Breeze multiple circuit electric connectors (built to Army Air Corps specifications), and EL–435 high-octane blending agent. Brief details. Aero Digest, July 1936, pages 62, 64. 5 illus.

Manufacturers of Fabricated Parts and Aircraft Materials. Aluminum alloys, baffles, camshafts, castings, forgings, cowlings, manifolds, collector rings, connecting rods, copper alloys, cork, crankcases, crankshafts, cylinder barrels and heads, fabrics, fiber, fittings, flexible tubing, gaskets, gears, glue, cement, wax, hardened and ground parts, hose clamps, insulated wire, insulating soundproofing materials, link pins, hardware, molybdenum, paint, dope, varnish, lacquer, enamel, pistons, plastics, pulleys, pumps, sheet packing, shielding, springs, stampings, steel, streamlinings, tanks, tie rods, valves, and valve guides, seats and inserts, wood and plywood, and zinc. Names and addresses of manufacturers. Aero Digest, July, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90.

Teleflex Remote Control. Flexible metallic cable for airplane controls. Description, characteristics, tolerances, efficiency, and precision. Revue de l'Armée de L'Air, June 1936, pages 705–709. 7 illus.

Tests on Dzus Self-locking Fasteners. F. K. Teichmann. Technical data and dimensions of various types of Dzus self-locking fasteners, their assembly and installation, and results of New York University tests which proved that the units possessed adequate strength characteristics and successfully withstand continued vibration. These fasteners are used for parts of the aircraft structure requiring quick assembly and disassembly for maintenance and accessibility. Aero Digest, July 1936, pages 34, 36.

The Tampier System. The Blocktube controls described comprise an articulated system of rigid push-pull members to control flying surfaces or motors. Aeroplane. June 17, 1936, page 779. 2 illus.

LIGHTING

Accessories from Croydon. Mechanism landing light illustrated and reference made to other Mechanism aircraft equipment. Flight, June 4, 1936, page 601. 1 illus.

Air Forces

FRANCE

Definitions of Airplanes for the French Air Force and Organization for Industrial Production. An interceptor type of airplane which should be light, swift, easy to pilot, capable of flying with one engine off, and well equipped for navigation and firing is recommended as a standard for the French Air Force. A second type of airplane for intelligence missions is suggested which would be derived from the standard design. Proposed new types of naval airplanes and airplanes for aircraft carriers are also defined. Systems for producing the airplanes and for their maintenance are discussed. Continuation. Les Ailes, June 4, 1936, page 6.

Companies of Soldier Parachute Jumpers. As a result of the successful Russian maneuvers with parachute jumpers, two companies have been formed in France. The role and organization of such units, suggested by Lieut. Colonel Desré, refer to: the landing of forces from airplanes at the rear or at a wing of the enemy equipment; covering an offensive operation on a large scale, aiming at the conquest of a distant objective with the use of mechanical apparatus and requiring the possession of an important point of land at a given instant; and missions of destruction. Brief abstract from Revue d'Infanterie. Revue de l'Armée de l'Air, June 1936, pages 699–700.

GREAT BRITAIN

Preserve Our Air Reserve. Cy Caldwell. Of the 1,340 Regular officers in the U.S. Army Air Corps, in the event of war, no more than 500 could be placed in the field as pilots of combat planes to protect four million square miles of territory and 150 million people. The list of regular officers is analyzed to reach this conclusion and the necessity for building up a larger force of Reserves is pointed out. The author regrets the lack of equipment for training Reserves and mentions that "in the Air Corps Tactical School, where the very latest didoes in air fighting are taught, there is not a single really modern combat plane." Aero Digest, July 1936, pages 21–23.

Reversal of the Method of Training Airplane Pilots. Major W. C. Ocker. Initial training of airplane pilots by blind flying is recommended and the development of blind flying traced. U.S. Air Services, July 1936, pages 27–29. 1 illus.

The Navy that Flies. Questions affecting the Fleet Air Arm. Effectiveness of aircraft bombing versus battleships is discussed and the differences in the functions of a ship-borne aircraft and shore-based aircraft, and of aircraft from a carrier and catapult aircraft are analyzed. Review of the Naval Air Section of Brassey's Naval Annual, 1936. Flight, June 11, 1936, pages 620–621. 3 illus.

On Expansion or Inflation. C. G. Grey. Production of airplanes for the expansion of the Royal Air Force and manifold difficulties which beset the Air Ministry contractors under the expansion program. Reference is made to the companies which will enter the manufacture of airplanes and engines. Mr. Grey remarks that there is not an American transport plane today that could not be beaten by any clever designer, provided he were adequately backed financially and could give service after sales. Aeroplane, June 10, 1936, pages 733–734. 1 illus.

English Experiments on the Training of Pilots in High-Speed Flight. G. H. Stainforth. Experiments made by English pilots during flights at high speed when training for the Schneider Cup competition. Abstracted from Luftwissen No. 3. Rivista Aeronautica, May 1936, pages 195–198.

Research and the Aircraft Industry. Question of whether the British aircraft trade should form an aeronautical research association of its own supported equally by the trade and the Government, or whether research should be undertaken by the Royal Aircraft Establishment and the National Physical Laboratory wholly at Government expense while the firms would carry on with private research at their own expense. Aeroplane, June 17, 1936, pages 765–766.

ITALY

The Potential Air Force of Italy. P. Naquet. Types of Italian military planes in 1924, in 1934, and in 1935. At the end of 1936 Italian aviation will be completely modernized but the airplanes of its air force are considered inferior in quality and quantity to the French equipment. L'Aérophile, May 1936, page 105.

SWEDEN

Sweden's Air Arm. General account of a visit to the Swedish Royal Air Force. Extensive use of British aircraft and engines built under license in Sweden, training, night flying, a new type of torpedo successfully dropped from a height of 50 meters, and civil ambulance work are briefly referred to. Flight, June 11, 1936, pages 626a–626d. 10 illus.

U. S. A.

The Air Reserve Forces. Organization of an air reserve force in the United States is of modest proportions: 174 modern airplanes including those in the course of construction, 181 airplanes in use, and 57 airplanes for transport or training, far from approaching the 980 airplanes recommended by the Baker Committee. Brief reference also to the proportion of pilots qualified for instrument flying, to the winter maneuvers, and to the Army order for 432 Wright 9-cylinder 1000-hp. Cyclones for the 82 Douglas and 13 Boeing bombers, and for whirlwinds for training planes. Revue de l'Armée de l'Air, June 1936. page 701.

Does the Navy Need Aircraft? Captain P. N. L. Bellinger. Functions of Naval aircraft in national defense are explained and planes based on battleships and cruisers, planes based on carriers, and the large flying boats operating from tenders and shore bases are discussed. The flying boat is recommended in place of the land plane because of the greater possibilities presented for the largest seaplanes. U.S. Air Services, June 1936, pages 19–22. 2 illus.

U. S. S. R.

Thirty-five hundred Russian Air Force cadets have qualified as pilots in the last year, 52,000 men learned to glide, and 25,000 "chemical instructors" have been trained. This year 8,000 cadets will receive flight instruction. Brief reference. Aeroplane, June 10, 1936, page 732.

Air Warfare

Aerial Bombardment. M. Lenoir. Percentage of the explosive necessary for the projectile to break up as well as drill the object bombed is calculated. Criticism of an article in the March issue which compared the effectiveness of dive bombing with bombing in horizontal flight. Statements in regard to attaining the objective, self-defense, and attack of ships are also criticized. Brief. L'Aérophile, May 1936, page 106.

On Air Pacts. C. G. Grey. Question of whether air power should be calculated in proportion to area, population, wealth, or vulnerability in peace pacts is referred to in a typical Grey discussion on political conditions in Europe. Aeroplane, June 17, 1936, pages 758–760.

Convoy of Pursuits for Bombers. A. Algasin, F. Kovaleff, A. Beliakoff, B. Kartacieff, M. Batacieff. Application of single and two-seater pursuit planes as convoys of the bomber formation and illustrations of rules for the attack by the pursuit planes in the direct protection of the bombers. Abstracted from the book entitled "The Tactics of Air Bombardment" by five Russians. Rivista Aeronautica, May 1936, pages 199–202. 3 illus.

New Ideas in the Design of a Structure for the Protection of an Anti-aircraft Shelter. G. A. D. A. Priolo. Current opinions regarding the study of anti-penetrating and anti-crash structures are criticized. Types of structures offering resistance to the penetration of the bomb are analyzed with preference for the deflecting structure. Various designs are discussed and illustrated and the necessity for systematic experiments emphasized. Rivista Aeronautica, May 1936, pages 183–191. 5 illus.

The Present Problems of Military Aeronautics. Offensive capacity of modern airplanes in military aviation, and in particular in bombardment, and the necessity for increasing the economy, regularity, and safety of military flights. Abstracted from Tecnica della Flotta Aerea, No. 3, 1936. Rivista Aeronautica, May 1936, pages 202–204.

Some Aspects of the New Theory of Firing Between Airplanes. Capt. C. Colangeli. Geometric-mathematical examination of the theory presented in the April issue for firing at a movable target at a great distance. The theory is based on the motion of the adversary appearing to approach the airplane. Possible varied contingencies of the struggle, the precision of some fundamental aspects, and the possible extension to firing in pursuit are taken up. Rivista Aeronautica, May 1936, pages 171–182. 16 illus.

The Bombardment of Homes. C. Rougeron. Effectiveness of bombing a city, proposed methods for increasing the resistance of urban homes to destruction, means for altering the effect of bombs, and results of dispersion of the population. Revue de l'Armée de l'Air, June 1936, pages 660–674.

The Decline of the Dog-Fight. B. J. Hurren.. "The speed and climb of modern machines will spell the end of hand-to-hand air fighting". Comparison of the performance of modern fighters with that of the early war-time types. The opinions are expressed that, as regards mass encounters of fighting aircraft, the fight must be conducted on dive-and-climb principles and that few pilots are able to dive effectively unless they have been trained to do so. By the diving attack suggested the complicated guesswork of deflection sighting of guns is said to be avoided. Flight, June 25, 1936, pages 686c–686d. 2 illus.

Flying Bombs. In the near future air squadrons will be able to bombard an objective from a distance of 10 to 15 km. by the use of flying bombs controlled automatically or from a distance. Very short reference to the opinion that extensive changes in air strategy and tactics may be expected from the use of such bombs now being secretly investigated. Les Ailes, June 18, 1936, page 6.

If, 193—? H. F. King. A conjectural story intended to tell something of what might be expected should Great Britain be attacked from the air after her Royal Air Force has been made stronger than it is today. Flight, June 25, 1936, pages 686c–688.

Land, Sea and Air Warfare. H. Nickerson. Attack on the importance of the airplane as a war weapon, and defense of the greater importance of land and sea forces. Airplanes are considered as "weapons of opportunity subject to many limitations from which ground arms are free" and are termed a "superlight calvary" and merely useful auxiliaries in combats between ground troops. Limitations of the airplane in air reconnaissance over land and sea, in coastal operations, and in bombing, as well as the effectiveness of anti-aircraft guns, are discussed. The day and night bombers of today are said to carry about the same weight of bombs as the good machines of 1918 although the radius is greater. Air activities are considered as having contributed little to the victory of 1918 and air activities in Syria, Morocco, Nicaragua, China, and Ethiopia are said to have had little effect. Bombing raids on cities are thought to have little value. Army Ordnance, July–August 1936, pages 7–14.